

WIN!
6 HAYNES
MANUALS
BOOKS
WORTH £137

3 FREE DIGITAL BOOKS
SAVE THE WORLD > 60 SECOND SCIENCE > BOOK OF SPACE

WORTH
£30



All About Space

15

**DEEP-SKY
TARGETS
TO SEE THIS
SUMMER**

**WHAT WOULD YOU
SOUND LIKE ON
ANOTHER PLANET?**

**MISSION TO
AN ALIEN
STAR SYSTEM**

**COULD A
PARTICLE
DESTROY THE
UNIVERSE?**

**WHAT DOES THE FUTURE HOLD FOR THE
SOLAR SYSTEM?**

NASA & ESA ANSWER YOUR QUESTIONS • PERSEVERANCE: NASA'S NEW RED PLANET ROVER • TOUR THE MOON



QUICKBUILD



J6002 Typhoon



J6009 Harrier



Aviation Royalty AMAZING AIRCRAFT OF THE RAF

The Harrier is a jet-powered attack aircraft capable of vertical/short take off and landing operations. Named after a bird of prey, it was originally developed by British manufacturer Hawker Siddeley in the 1960s and emerged as the only truly successful V/STOL design of the many attempted during that era. It was conceived to operate from improvised bases, such as car parks or forest clearings, without requiring large and vulnerable air bases. Later, the design was adapted for use from aircraft carriers.

The Eurofighter Typhoon is a twin-engine, canard-delta wing, multi-role fighter. It was designed originally as an air superiority fighter and is manufactured by a consortium of Airbus, BAE Systems and Leonardo. One of the world's most capable fighter aircraft, it possesses all the attributes that made the Spitfire so successful in combat and is the most effective air defence fighter to ever serve with the RAF.

You can create your very own fighters of the RAF at home with an Airfix QuickBuild kit. QuickBuild kits allow you to recreate a wide variety of iconic aircraft, tanks and cars into brilliant scale models. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

- **Compatible with other plastic brick brands**
- **Features a self-adhesive sticker sheet for authentic decoration**
- **Includes a stand to show off your handy work.**

Collect them all! Check out the rest of the range online.



J6018 Red Arrows Hawk



J6004 Apache



J6001 MESSERSCHMITT



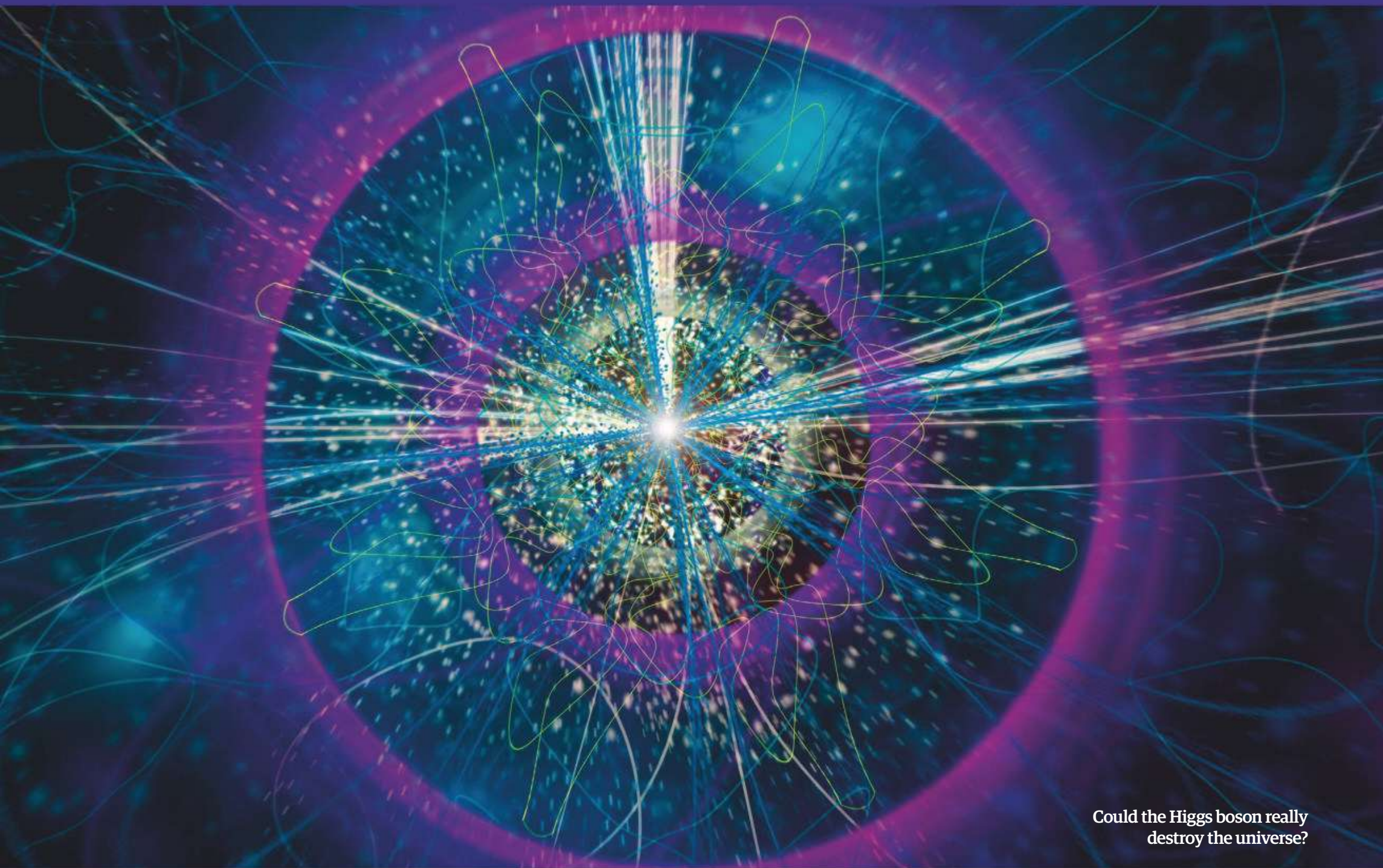
1 x Rolls-Royce Pegasus Mk. 105 vectored thrust turbofan



2 x Eurojet EJ200 Afterburning Turbofan



GET FREE ALL ABOUT SPACE BONUS CONTENT
SIGN UP ONLINE AT SPACEANSWERS.COM/NEWSLETTER



Could the Higgs boson really
destroy the universe?



Welcome

This month **All About Space** takes a look into the distant future of our very

own Solar System. It's a time where Mars loses a moon and gains a ring, our Sun swells into an all-encompassing red giant - eventually evolving into a black dwarf - Earth's surface reaches blisteringly hot temperatures and there's a bit of a stellar jig as a selection of stars in the universe swing closer to our solar neighbourhood. The Solar System is the model of stability but, as you'll discover this issue, that's all evidently about to change.

Keeping in with the theme of the Solar System, we head to Mars this month as - at the time of writing - NASA prepares to send its new rover, Perseverance, to the surface of the Red Planet. Scheduled for launch

on 17 July, the spacecraft will land on 18 February next year to begin hunting for signs of life, additionally collecting rock and soil samples with the aim of returning them to Earth for further investigation.

Also this month, we take you on a tour of the night sky, so get ready to feast your eyes on a gaggle of galaxies, sizzling summer nebulae, planets and, of course, our Moon.

You might have noticed that **All About Space** has been missing from the newsstand for a number of issues due to the coronavirus pandemic. However, I am pleased to confirm that the magazine will be available in supermarkets and newsagents again from, and including, issue 106.


Gemma Lavender
Editor-in-Chief

Our contributors include...



Kulvinder Singh Chadha
Space science writer

July 2012 saw the discovery of the Higgs Boson. But could the particle really destroy the universe? Turn to page 32 to find out.



Stuart Atkinson
Astronomer

Discover how to get the very best views of the Solar System and beyond with Stuart's full guides on catching the planet of the month, lunar craters and more.



Peter Beck
CEO of Rocket Lab
Peter reveals how his company is developing the latest in rocket technology, NASA's involvement and what's next on the space exploration agenda.



Lee Cavendish
Staff writer

Turn to page 38 for Lee's report on what we can expect from NASA's new rover, Perseverance. Like Curiosity, find out how it will hunt for life.

ALL ABOUT SPACE ISSUE 106
ON SALE 16 JULY!

Available from supermarkets, newsagents and
online at myfavouritemagazines.co.uk

CONTENTS

www.spaceanswers.com



TWEET US
@spaceanswers



POST ON FACEBOOK
/AllAboutSpaceMagazine



SEND US AN EMAIL

space@spaceanswers.com

LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

06 SpaceX makes history by flying two NASA astronauts to the Space Station aboard the Crew Dragon for the very first time



FEATURES

14 **Future of the Solar System**

It may be a model of long-term stability, but our solar neighbourhood's future holds some spectacular changes

22 **Future tech Satellite repair droids**

24 **Destination Alpha Centauri**

Some of the world's top scientists are looking to reach for our nearest stars

32 **The Higgs boson**

Could this particle really destroy the universe?

38 **Prepare for Perseverance**

NASA sends its next-generation rover to the Red Planet - here's what to expect from the mission

46 **Interview The man behind Rocket Lab**

The CEO of the private spaceflight company, Peter Beck, talks exciting plans for the future

52 **What would you sound like on other worlds?**

How your voice would differ if you were able to talk on another planet or moon

56 **Focus on Nancy Grace Roman Space Telescope**

58 **Sizzling summer nebulae**

Take a tour of some of the treasures held in the warm Northern Hemisphere

64 **Ask Space**

Your questions answered by our space experts



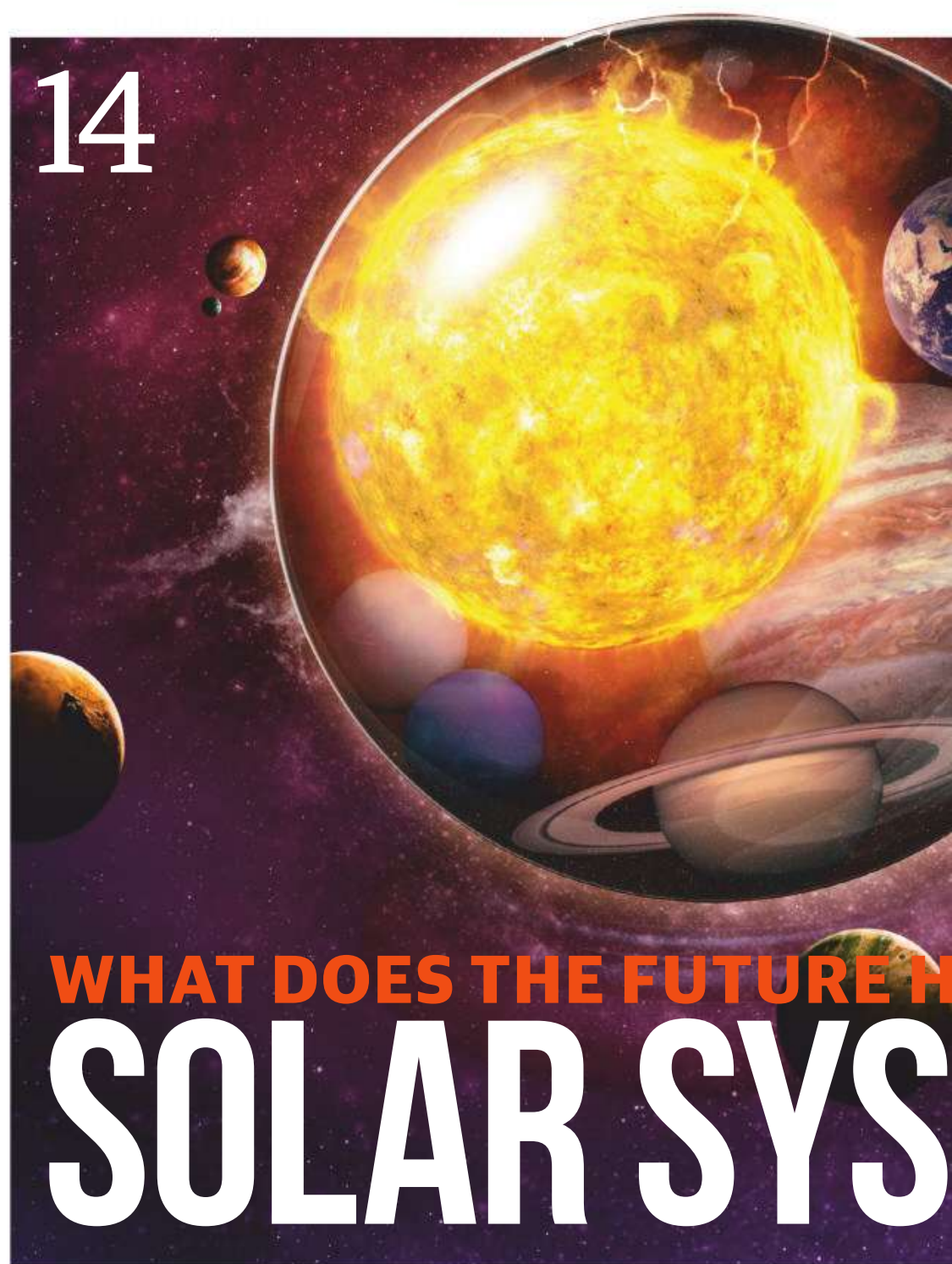
SPECIAL OFFER!
3 FREE HAYNES POCKET MANUALS

HOW IT WORKS

Subscription offer

TURN TO **PAGE 50** FOR DETAILS

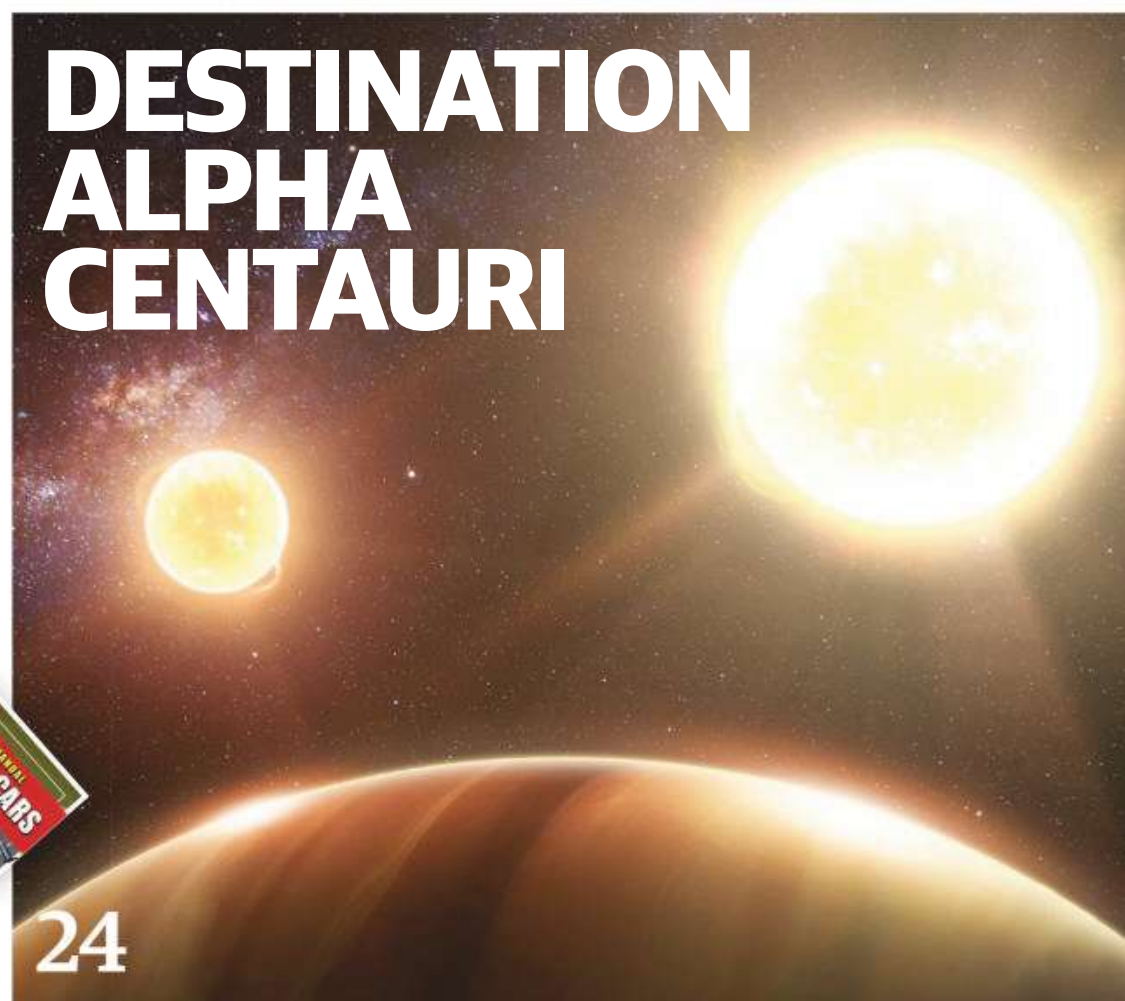
14



WHAT DOES THE FUTURE HOLD FOR OUR SOLAR SYSTEM?

DESTINATION ALPHA CENTAURI

24



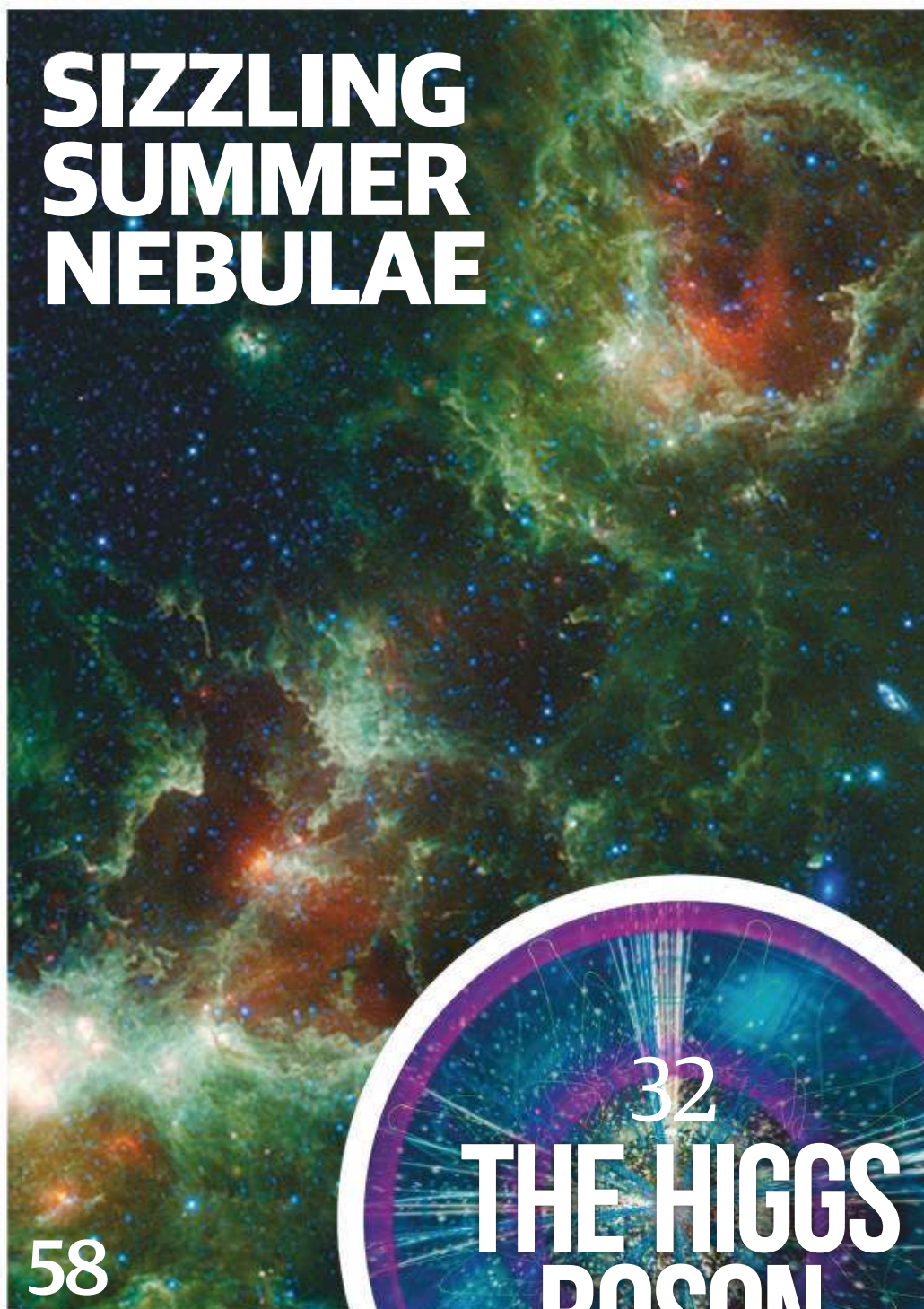


3 FREE eBOOKS WORTH £30!

31 Explore science and the history of the universe, and find out what you can do to save our home planet from climate change



OLD FOR THE TEM?



SIZZLING SUMMER NEBULAE

58

32 THE HIGGS BOSON

STARGAZER

Your complete guide to the night sky

68 What's in the sky?

Although the sky never truly gets dark, embrace the challenge of summer stargazing

72 Month's planets

There will be a lot to observe in the sky around Venus over the next few weeks

74 Moon tour

How to find one of the most striking but overlooked craters on the lunar surface

75 Naked eye and binocular targets

There are fascinating targets to see in the night sky

76 Deep sky challenge

There's no need to put your telescope into hibernation on light summer nights

78 The Northern Hemisphere

Plenty of targets for those armed with the right kit

80 Telescope review

Is the Celestron NexStar 6SE the right telescope for you? Here's our lowdown



38 PREPARE FOR PERSEVERANCE

WIN! SIX HAYNES SPACE MANUALS



WORTH £137!

13

Nighttime rover exploration

Unfortunately you can't test a rover's ability to traverse the Moon without actually going there. European Space Agency (ESA) engineers have done the next best thing: drive a test rover across Tenerife at night in order to simulate the low-light conditions on the lunar surface.

Tenerife's Teide National Park recently accommodated the ESA's Heavy Duty Planetary Rover to gain experience with the craft's navigation hardware and software on volcanic and rocky ground. This terrain at night is supposed to simulate the conditions at the Moon's poles, which the space agency hopes to explore in the near future.



Blue marks the spot for baby stars

This is certainly a peculiar galaxy, but it is no less beautiful. The Hubble Space Telescope observed the enormous NGC 4100, and highlighted the regions where new, young stars are being born.

In a galaxy's spiral arms, gas and dust can lay dormant for billions of years, but when gravity pulls material together, it kick-starts explosive star formation. This stellar inception causes Herculean emissions of radiation that illuminate the surrounding gas - Hubble has picked this out as bright, blue patches.

© NASA/ESA & Hubble

Hubble captures a comet's demise

It's not every day that Hubble captures a comet in the process of breaking up. Comet C/2019 Y4 (ATLAS) was first discovered in December 2019 by the Asteroid Terrestrial-impact Last Alert System (ATLAS) in Hawaii and continued to gain attention as it became brighter and brighter.

This gradual illumination abruptly ended, and Hubble was able to show that this was because the comet was breaking up into roughly 30 pieces. These fragments were being stripped of their layers due to the unfiltered rays of the Sun and produced a remarkable solar-swept tail of dust.

© NASA/ESA



Watching the birth of a planet

This is not the eye of a tornado; something far less destructive is happening in this image. Taken with the European Southern Observatory's (ESO) Very Large Telescope (VLT), new worlds are in the process of being born 520 light years away from Earth. This polarised image of the young star AB Aurigae shows a huge disc around it containing dust, gas and rock caught in a spin. Within the brighter spots, rocks are accreting more and more mass, which will eventually bring enough material together to form planetesimals.

Liftoff! SpaceX launches first astronauts for NASA on historic test flight

Words by Amy Thompson

SpaceX launched astronauts for the first time ever today, making history and beginning a new age of commercial spaceflight. A Falcon 9 rocket lifted off from historic Pad 39A at NASA's Kennedy Space Center on 30 May at 20:22 BST carrying SpaceX's Crew Dragon capsule into orbit.

The launch kicked off SpaceX's landmark Demo-2 mission, which is sending NASA astronauts Bob Behnken and Doug Hurley to the International Space Station (ISS). Demo-2 marks the return of orbital human spaceflight to US soil after a nearly decade-long absence, and it signals the beginning of a new era in space exploration - one led by commercial companies. "It was incredible," Hurley radioed SpaceX's launch control. "Appreciate all the hard work, and thanks for a great ride to space."

US President Donald Trump and Vice President Mike Pence were on hand to watch the launch live from the Kennedy Space Center. Trump told reporters ahead of the launch that he felt an obligation as president to watch the historic liftoff.

Shortly after launching Hurley and Behnken into orbit, SpaceX also notched another rocket landing under its belt. The Falcon 9 booster's first stage made a smooth landing on SpaceX's drone ship Of Course I Still Love You in the Atlantic Ocean.

The launch was originally scheduled to occur on Wednesday 27 May, but bad weather forced the NASA-SpaceX team to scrub that attempt about 20 minutes before liftoff. In addition to Trump and Pence, huge crowds were expected to watch SpaceX's first crewed launch.

While NASA cautioned space fans not to travel to the launch site due to the ongoing coronavirus pandemic, the launch took place as Florida is reopening its businesses. The Kennedy Space Center Visitor's Complex, for example, reopened its doors on 28 May. A day earlier the first launch attempt drew an estimated 150,000 spectators to Florida's Space Coast.

Demo-2 is the final test before NASA can fully validate Crew Dragon and the Falcon 9 for human spaceflight. Once that happens SpaceX can start flying astronauts to and from the space station on a regular basis. Behnken and Hurley arrived at the space station safely on 31 May at 13:16 BST. They docked at the station's Harmony module and will remain parked there for one to four months.



Pad 39A is also the site from which the Apollo 11 astronauts launched



New marsquake study could shatter theories on how Mars was born

Words by Gemma Lavender

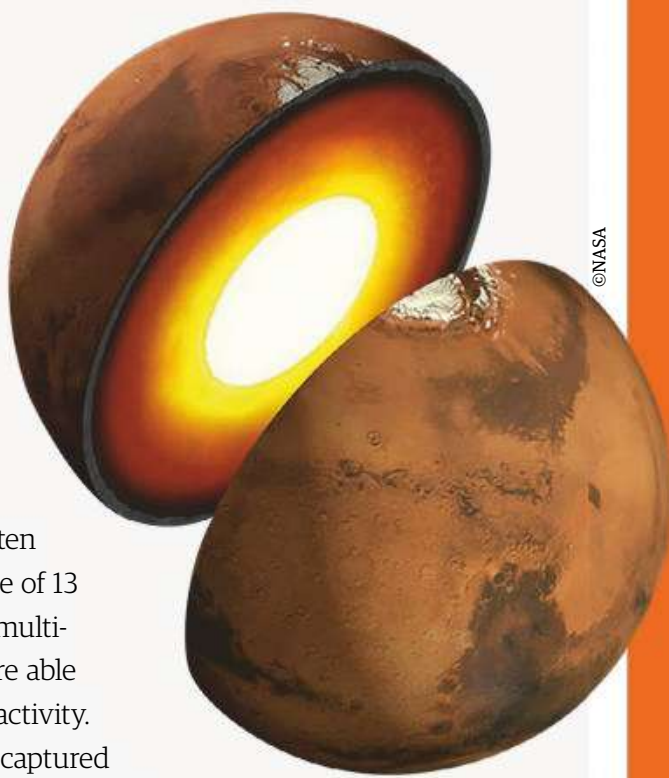
A team of researchers based at the University of Tokyo has revealed tantalising details about Mars' seismic activity for the very first time. These new results could make or break theories surrounding the Red Planet's origins and provide details about its composition.

The fourth rock from the Sun might be one of the closest worlds to us - swinging between distances of 55 million and 400 million kilometres (34 million and 249 million miles) dependent on its position and Earth's position relative to our star - but it is often much safer and less expensive to investigate the Red Planet through simulations on Earth, rather than launching a spacecraft.

No one knew this better than Keisuke Nishida, an assistant professor at the University of Tokyo's Department of Earth and Planetary Science, and his team, who delved deep into the Red Planet by mimicking the conditions in the planet's uppermost core with the help of a molten iron-sulphur alloy, which they brought to a scorching melting-point temperature of 1,500 degrees Celsius (2,732 degrees Fahrenheit).

Crushing the molten mix under a pressure of 13 gigapascals using a multi-anvil press, they were able to measure seismic activity. In this case Nishida captured P-waves travelling at a velocity of 4,680 metres (15,354 feet) per second through the alloy and snapped images of the action using X-ray beams from two synchrotron facilities: the Photon Factory, which forms part of Japan's High Energy Accelerator Research Organization, and SPring-8 in Harima Science Park City, Hyogo Prefecture, Japan.

Using Nishida and his team's findings, planetary researchers could read Martian seismic data to find out whether or not the Red Planet's core consists primarily of iron-sulphur, Nishida said. "If it isn't, that will tell us something of Mars' origins," Nishida said. "For example, if Mars' core includes silicon and oxygen it suggests that, like Earth, Mars suffered a huge impact event as it formed. So, what is Mars made of and how was it formed? I think we are about to find out."



©NASA

Massive galactic disc could change our understanding of galaxies

Words by Chelsea Gohd

A massive, rotating disc galaxy that first formed just 1.5 billion years after the Big Bang could upend our understanding of galaxy formation, scientists suggest in a new study.

In traditional galaxy formation models and according to modern cosmology, galaxies are built beginning with dark-matter halos. Over time those halos pull in gases and material, eventually building up full-fledged galaxies. Disc galaxies, like our own Milky Way, form with prominent discs of stars and gas and are thought to be created in a method known as 'hot-mode' galaxy formation, where gas falls inward towards the galaxy's central region where it then cools and condenses.

This process is thought to be fairly gradual, taking a long time. But the newly discovered galaxy DLA0817g, nicknamed the 'Wolfe Disc', which scientists believe formed in the early universe, suggests that disc galaxies could actually form quite quickly.

Led by Marcel Neeleman of the Max Planck Institute for Astronomy in Germany, researchers spotted the Wolfe Disc using ALMA, the Atacama Large Millimeter/submillimeter Array in Chile. They found out that the object was a large, stable, rotating

disc, clocking in at a whopping 70 billion times the mass of our Sun.

Researchers suggest that the galaxy - which appears as it was when the universe was just 1.5 billion years old, or ten per cent of its current age - might have formed by a process known as 'cold-mode accretion'. They think that the gas falling in towards the galaxy's centre was actually cold, so because the gas didn't need time to cool down as it approached the galactic centre, the disc was able to more rapidly condense.



The disc galaxy is 70 times the mass of our Sun

©NRAO

HOW IT WORKS

Subscription offer

FROM £2.38 PER ISSUE!

ENJOY INSTANT READING

Our digital editions come with the same features included in the print edition!



This offer is **only** available via our online shop

www.myfavouritemagazines.co.uk/hiwd/DIGCSP20

Love isolation? NASA wants you to spend eight months locked in a Russian lab

Words by Chelsea Gohd

Do you thrive in social isolation? NASA is looking for people to spend eight months locked in a Russian lab for a new experiment. When humans return to the Moon and travel to Mars, they will need to be prepared for long-duration space travel and even longer stays on these far-off destinations. Currently NASA's Artemis program aims to land humans on the Moon for the first time since NASA's Apollo 17 mission landed in 1972.

While the Moon is the main goal of NASA's Artemis program, the agency's larger goal is to send crewed missions to Mars. But long-term space travel and habitation won't be easy. Such missions will present both physical and mental challenges as astronauts work to not only survive, but perform important scientific research in uniquely difficult environments.

In the upcoming NASA-Russia experiment - which builds upon a previous four-month-long study from 2019 - a crew will live in isolation in a closed facility at Russia's Institute for Biomedical Problems, which is in Moscow, NASA officials said in a statement. This habitat facility was



used in 2011 for a notable series of Russian mock Mars missions known as Mars500. During these missions, crews spent 520 and 105 days - on two separate missions - in the facility.

Participants that join the experiment's crew will spend eight months inside a closed facility that according to the statement will have "environmental aspects similar to those astronauts are expected to experience on future missions to Mars."

The crew will spend these months living together in isolation and working on scientific research. They will even virtually conduct experiments that future astronauts might be expected to perform on locations like the lunar surface.

Above: Could you spend eight months isolated with a small crew?

First super-fast pulsar found snacking on companion in far-flung star cluster

Words by Gemma Lavender

China's Five-hundred-meter Aperture Spherical Telescope (FAST) has uncovered the first known pulsar in Messier 92, a globular star cluster roughly 27,000 light years away in the constellation of Hercules. The swiftly spinning and pulsating object, which goes by two names - PSR J1717+4307A and M92A - forms one part of an eclipsing binary

system in which it is siphoning material from a stellar companion.

A research team led by Zhichen Pan and Di Li from the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC), which operates FAST, has shown that M92A spins at a rapid speed of 316.5 rotations per second and co-orbits a star lighter than our Sun, weighing in at 0.18 solar masses.

Using FAST the researchers observed two eclipsing events in the binary system - when one object passed in front of the other from Earth's point of view. One eclipse lasted around 5,000 seconds, and the second, which arrived between 1,000 and 2,000 seconds later, lasted for 500 seconds. M92A is known as a millisecond pulsar, a souped-up version of the slightly slower moving pulsar. Millisecond pulsars are highly magnetised neutron stars which pirouette rapidly at speeds less than 30 milliseconds.

Left: The binary pair was spotted in Messier 92

Right: Galileo data is still revealing exciting new things about Jupiter and its moons



Scientists peer back in time to find new evidence for watery plumes on Europa

Words by Chelsea Gohd

Scientists looked back in time to offer new evidence suggesting that plumes of water vapour shoot out into space from Jupiter's moon Europa. In this new study researchers used observations made by the Galileo spacecraft to simulate the movement of positively charged subatomic particles called protons near the moon. While flying by the icy world in 2000, Galileo found fewer protons around Europa than researchers expected. They chalked this up to issues with the probe's instrument.

The team found that some of these 'missing protons' weren't registered because a water plume shooting out from the moon blocked them from the instrument. A different instrument on Galileo conducted magnetic field studies of the moon, and the researchers were able to show a disruption in nearby magnetic fields when the plume shot out to support their theory. The ESA aims to probe this world closer with its highly anticipated Jupiter Icy Moons Explorer in 2022, while NASA will be launching the Europa Clipper spacecraft in 2024.



WIN

A SELECTION OF HAYNES MANUALS

Courtesy of Haynes Publishing, you could win six of the finest books on awe-inspiring aspects of space

Apollo 11: 50th Anniversary Edition £22.99

To commemorate the golden jubilee of the Apollo 11 mission, Haynes released a special edition of this manual. Documenting all the hardware, software, vehicles and everything you need to know about the most famous space exploration mission, see how man reached the Moon.

Large Hadron Collider Manual £22.99

Peering into the quantum world, the Large Hadron Collider, situated at the CERN laboratory on the Franco-Swiss border, is at the forefront of research concerning the universe's smallest particles. This guide will take you through how it works and what its results could mean for our understanding of the universe.

Milky Way Manual £22.99

A fine overview of our home galaxy. The Solar System is just one small part of an enormous disc full of stars, planets, supernovae and a Herculean black hole known as Sagittarius A* sitting at the centre of it all. This book will walk you through our galaxy's formation and evolution since its cosmic inception.

Moon Manual £22.99

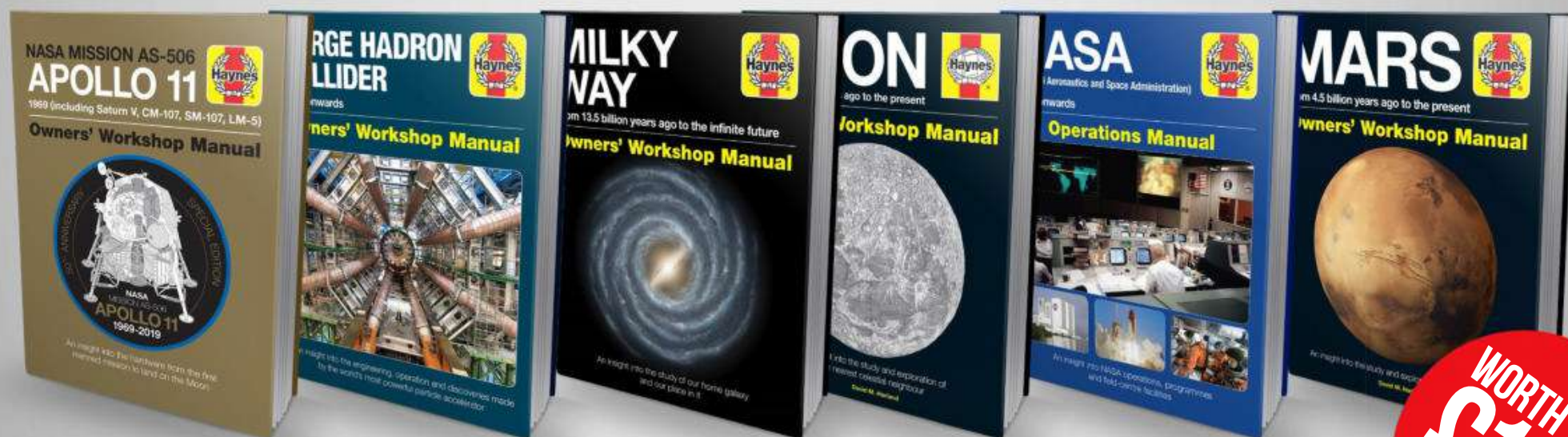
Everyone looks up into the night sky and stares at our only natural satellite, the Moon. This manual details the geology of the Moon and how it has moulded into its present form. The book also includes information on the exploration missions that have visited this distant terrain to reveal its secrets.

NASA Operations Manual £22.99

What is your favourite NASA mission of years gone by? Is it Gemini? What about the Space Shuttle adventures, the Hubble Space Telescope or Apollo? There is much that goes on behind the scenes to run these missions, the NASA Operations Manual provides a peek behind the curtain.

Mars Manual £22.99

As global space agencies prepare to explore Earth's neighbouring planet, Mars, it is worth understanding why. This manual provides a unique insight into the fourth rock from the Sun, including past and present observation missions and how they are now searching for signs of ancient microbial life.



WORTH OVER
£137

To be in with a chance of winning, answer this question:

On 2 July 1985, the European Space Agency launched Europe's first deep-space mission, Giotto. Which famous comet did it fly past, providing the first close-up images of a comet's nucleus, on 13 March 1986?

A: Comet Shoemaker-Levy 9 **B:** Halley's Comet **C:** Comet 67P/Churyumov-Gerasimenko

Competition ends on 16 July 2020

Enter online at spaceanswers.com or by post to
All About Space competitions, Quay House, The Ambury, Bath, BA1 1UA

Visit the website for full terms and conditions at futureplc.com/terms-conditions/



WHAT DOES THE FUTURE HOLD FOR THE SOLAR SYSTEM?

It may be a model of long-term stability, but our solar neighbourhood's future holds some cataclysmic events and spectacular changes

Reported by Giles Sparrow

Ever since it settled down from a period of early turbulence about 4 billion years ago, our Solar System has provided a more or less stable home to Earth and the other planets and bodies that orbit the Sun. But how long will it stay that way? It's certain that the Sun is ultimately doomed to brighten and swell enormously in size, becoming a red giant whose bloated outer atmosphere will threaten to engulf the Solar System's inner worlds 7 billion years from now - but long before then there are sure to be other changes that alter our planet and others, perhaps beyond recognition.

In the relatively near future, it is tidal forces between planets and their satellites that are likely to have the most impressive effects. These arise as angular momentum is transferred between the planet and moon due to tides on the planet and in response to the moon's gravity, resulting in a consistent 'tug' on the moon's orbit. For most moons in the Solar System the result is that the satellite slowly spirals away from the

Future of the Solar System

planet, while the planet slows its rotation. This is what is happening in our own planetary system - the Moon gets an average of 3.8 centimetres (1.5 inches) farther away from Earth each year, while Earth's rotation slows by 1.7 milliseconds per century. Over millions of years the orbits of most moons in the Solar System will get wider.

But for a couple of moons, the opposite is happening - they're slowly spiralling towards their planets. One of these is Phobos, the inner of Mars' two rocky moons - but why is it different? "The inward migration of Phobos is due to the fact that its orbital period is slightly shorter than the rotational period of Mars," explains Professor Ben Black of the City University of New York. "The Martian tidal bulge tugs at Phobos like a dog-walker pulling on a leash." Alongside graduate student Tushar Mittal, Black recently looked at the Martian moon's future evolution, suggesting that in about 20

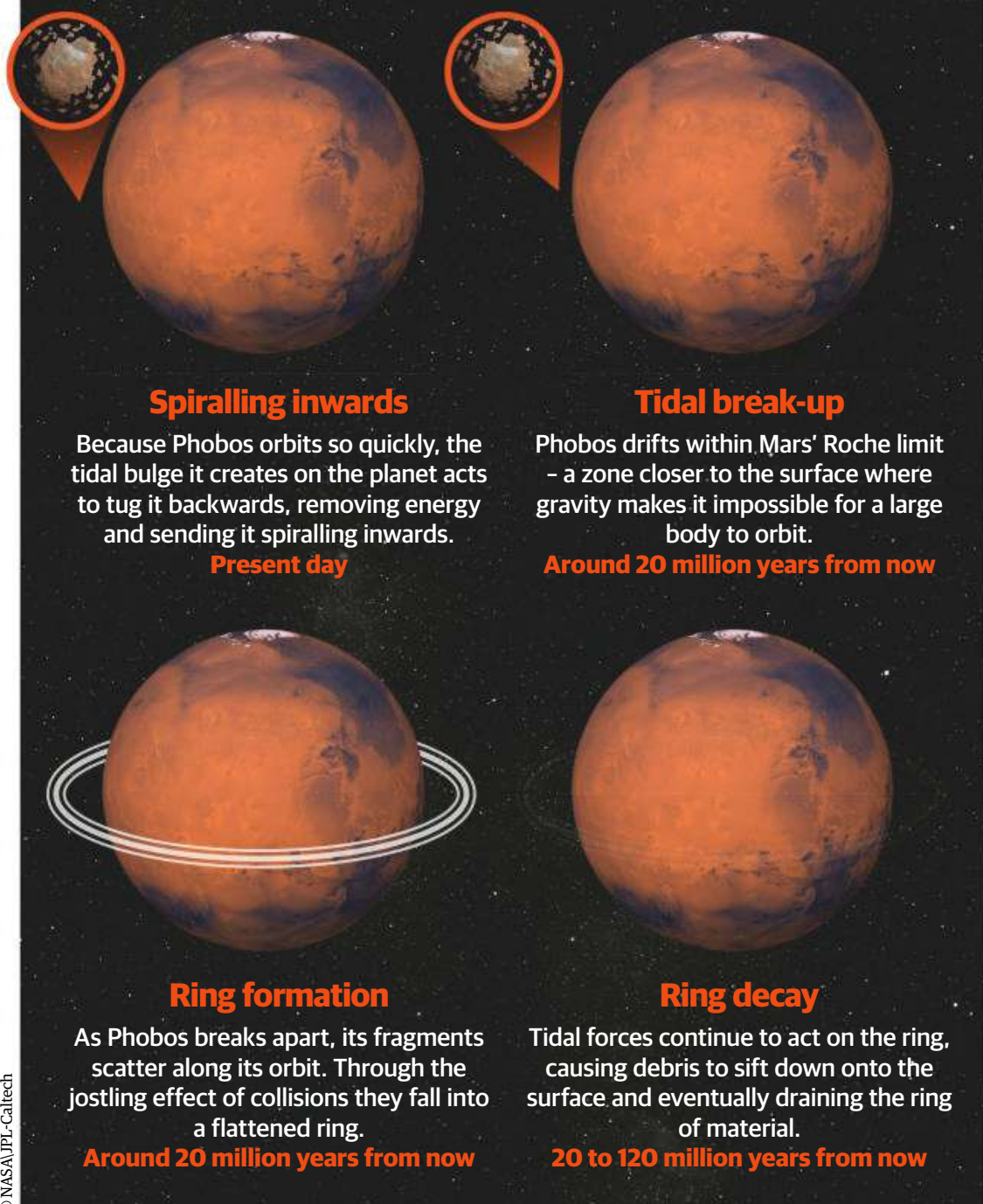
to 40 million years from now Phobos may reach a crisis point when it gets too close to Mars.

Previous calculations had revealed how long it would take for the 22-kilometre (14-mile) moon to migrate inwards, but Black and Mittal's work suggests Phobos might not make it that far. "We predict that Phobos won't make it all the way to Mars, but instead will break apart sooner than that," says Black. "We find that the key to Phobos' fate is its strength. If Phobos is sufficiently strong, tidal stresses won't be able to tear it apart, and it will crash into Mars intact. But the evidence points to Phobos being very weak."

"We considered the possible fates of Phobos in a self-consistent manner and utilised models developed in terrestrial rock physics - geotechnical models like those used in the construction of tunnels," adds Mittal. And the result? Phobos' structural weakness means that it will disintegrate

How Mars will gain a ring

The disintegration of inner moon Phobos will create a ring around the Red Planet about 20 million years from now



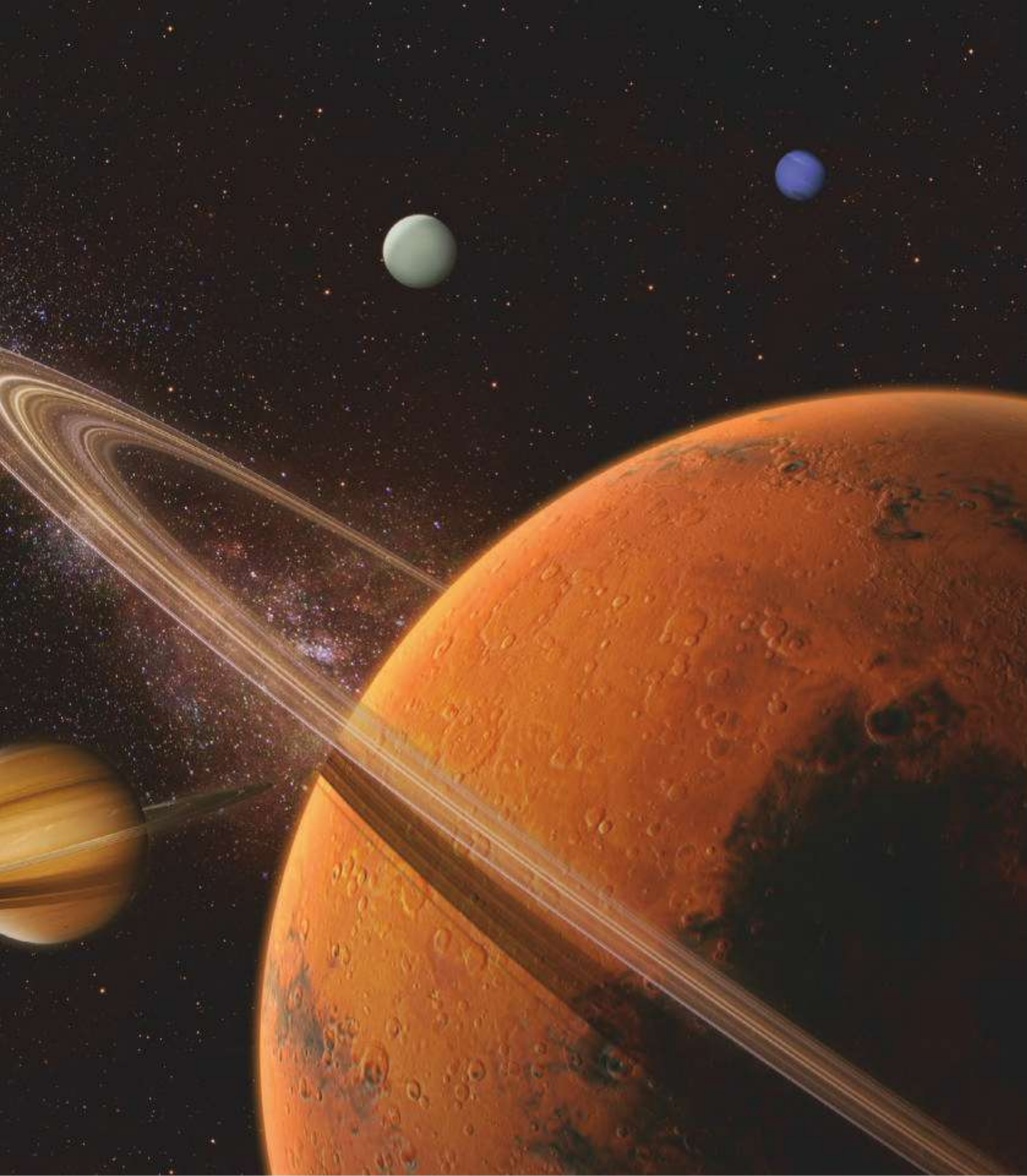
Above:
An artist's impression of Mars' future ring system, comprised of debris left over from Phobos



to form a rocky ring system around the Red Planet, similar to the icy ones seen today around planets like Saturn. "The lifetime of the ring will depend on how far Phobos is from Mars when a break-up occurs," points out Black, "but we estimate that the ring will persist for in the ballpark of 1 to 100 million years."

Beyond tidal forces, gravity has another important role to play in the future of the Solar System - one whose effects can be remarkably hard to predict. 'Orbital resonances' occur when one object has an orbital period close to an exact multiple of another. This produces frequent close alignments between the two, magnifying otherwise weak gravitational forces and potentially disrupting apparently stable orbits. A present-day example would be the 'Kirkwood gaps' - regions of the asteroid belt between Mars and Jupiter that are empty because any object orbiting within them would be in resonance with Jupiter. But in the longer term, a different resonance with Jupiter might cause far more dramatic results.

Mercury, the innermost planet, has the most eccentric orbit of all, and the long axis of this orbit



“AS THE SUN BRIGHTENS, THE HABITABLE ZONE WILL ALSO EXPAND, LEAVING EARTH BEHIND IN ABOUT 1 BILLION YEARS”

ROBERT SMITH

wobbles or ‘precesses’ around the Sun at a rate of 1.5 degrees every thousand years. Jupiter’s orbit, though less eccentric, precesses at a very similar rate, which could potentially allow their orbits to line up in a resonant arrangement around 3 to 4 billion years from now. If this was to happen, Mercury’s orbit could eventually go haywire, flinging it onto a chaotic course that could send it hurtling into the Sun, or even cause it to collide with Venus or Earth.

In 2009 French astronomers Jacques Laskar and Mickaël Gastineau attempted to estimate the chances of such an event happening. Over 2,500 computer simulations, each of which varied the initial position of Mercury by a metre, found that Mercury’s orbit evolved to threaten the other planets one per cent of the time. The tests reveal

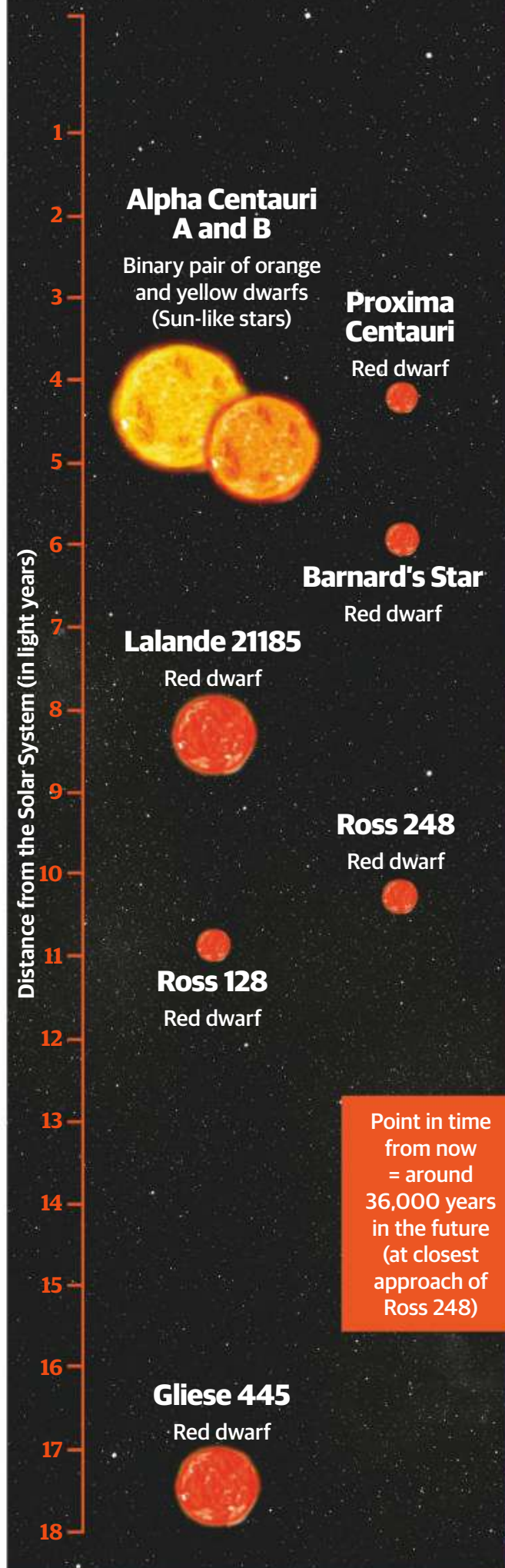
an example of ‘sensitivity to initial conditions’ – better known as chaos theory – which has profound implications for any attempt to track the long-term orbits of the planets.

Chaos theory doesn’t mean that a system ignores the laws of physics – only that those laws operate in such a way that tiny differences in initial parameters magnify over time until they make prediction impossible. In our Solar System this means that unless you can pin down the exact positions, orbital speeds and masses of the eight major planets and countless smaller objects with near-absolute precision, attempts to model the evolution of orbits become useless after a certain point in the future. Estimates of exactly how soon we ‘lose track’ of various Solar System parameters

Future of the Solar System

Stellar switch

The next 100,000 years will see many stars make close approaches to our Solar System, though none should come close enough to threaten the inner planets

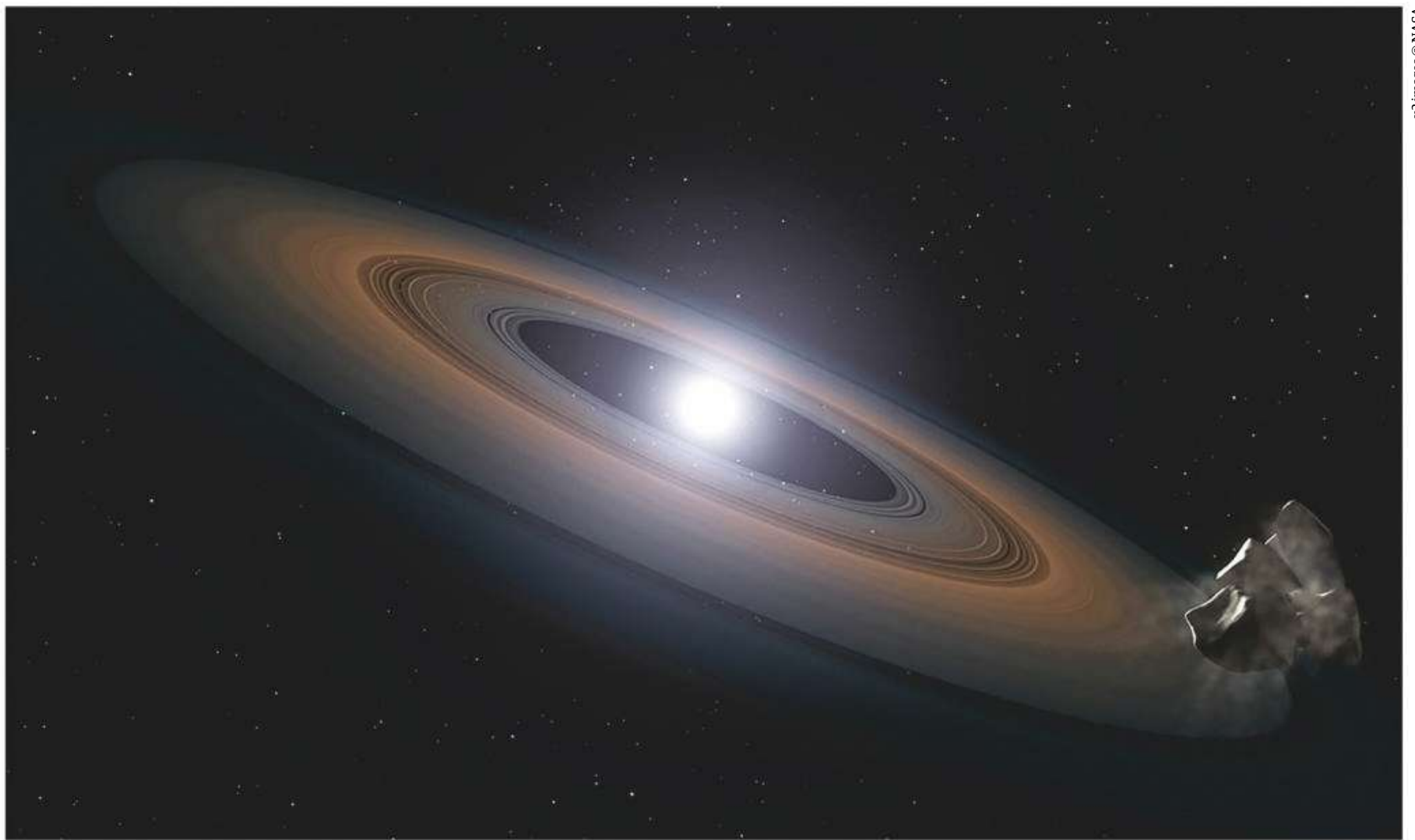


Future of the Solar System

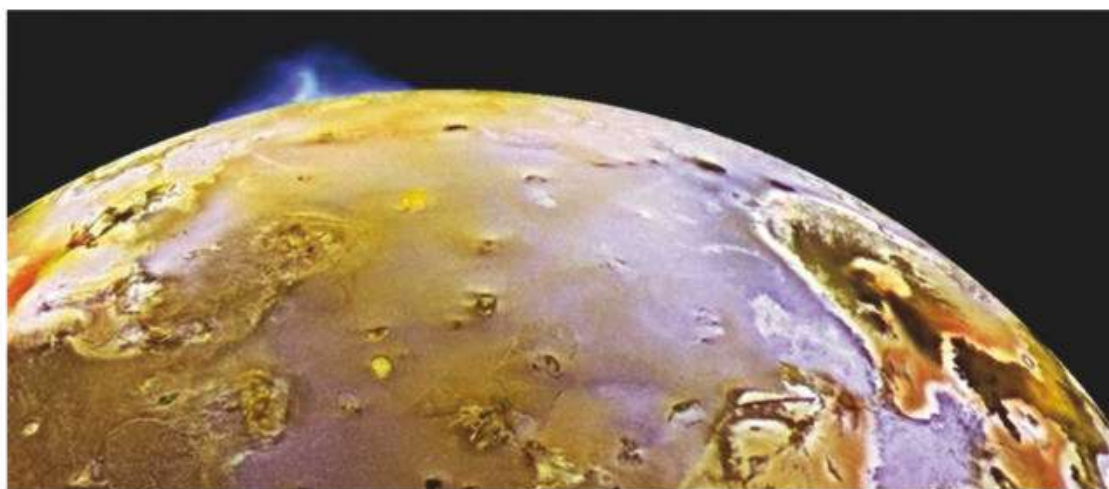
Right (clockwise): The discovery of debris discs around burnt-out white dwarfs suggests they could give rise to new planetary systems, even after destroying their old ones

Arcturus, in the constellation of Boötes, is a solar-mass star some 37 light years from Earth which has recently begun its expansion into the red giant stage of its life

Volcanoes on Jupiter's moon Io are driven by heating from tidal forces, but as Io spirals away from the planet these forces will weaken and the moon will cool



x3 images © NASA



range between 2 and 200 million years - beyond that point the positions of the planets and even the shape of their orbits are unpredictable using present-day models.

Another complicating factor is the gravitational influence of other stars. Today the closest known star to Earth is Proxima Centauri, a small red dwarf some 4.24 light years from Earth, but astronomers have calculated the motion of other stars in the solar neighbourhood and found that several will come much closer than that in the next thousands of years - perhaps even close enough to have their own effect on the orbits of the outer planets and the icy objects of the Kuiper Belt and Oort Cloud.

While we are uncertain about the destiny of the planets beyond a certain point in the future, we're on firmer ground when it comes to the fate of the Sun itself. As it continues to shine by the process of nuclear fusion of the hydrogen in its core, the Sun will brighten slowly but steadily over the

next 4 billion years, at a rate of about one per cent every 100 million years or so. This will have severe consequences for the habitability of our own planet and others, but these consequences are nothing compared to what comes next.

In about 7 billion years from now the Sun will exhaust the hydrogen fuel in its core and begin to go through a series of dramatic changes. The exhausted helium-rich core will begin to contract, releasing gravitational energy, while hydrogen fusion moves out into a surrounding shell. About half of the energy released by the contracting core is available to raise its temperature. Eventually this makes it hot enough for the helium to undergo nuclear reactions, producing carbon and oxygen, but in the short term it also heats the hydrogen-burning shell, causing fusion to run faster than it did in the core and increasing the Sun's energy output at least a thousandfold. The other half of the energy drives the expansion of the Sun's upper layers, using them

to balloon outwards and creating a bloated, brilliant monster with a surprisingly cool surface - our Sun will become a red giant.

But just how large will the red giant Sun become, and will it threaten to engulf the planets that it has previously provided with light and heat? Robert Smith of the University of Sussex researched these questions with his colleague Klaus-Peter Schröder of the University of Guanajuato, Mexico, and reveals a surprising factor that complicates the question: "As the Sun becomes larger, the surface gravity also decreases, and mass is less strongly bound to the surface. Mass loss caused by the solar wind [the stream of particles blowing out from the Sun's surface] therefore increases steadily and becomes significant. By the time that helium ignition takes place in the core, the Sun will be more than 200-times larger than it was on the main sequence, reaching out beyond Earth's current orbit. But it will also have lost about 20 per cent of its mass."

The Solar System's changing planets

As the Sun swells to a red giant, it will have a dramatic effect on the planets and their moons

Neptune

The outermost of the major planets, Neptune orbits so far from the Sun that it will never make it out of deep freeze, even when the Sun is at its biggest and brightest.

Uranus

The innermost of the Solar System's two ice giants, Uranus will experience habitable temperatures, warm enough to melt ice on the surface of its moons, for just 2 million years.

Saturn

Saturn's atmosphere will also expand, and its rings will likely be long gone. Its moons, including the giant Titan, may benefit from 8 million years at habitable temperatures.

Jupiter

Increased solar heating will cause Jupiter's atmosphere to balloon in size. Its giant moons will enjoy a habitable phase lasting around 30 million years.

Mars

Our outer neighbour will probably survive the Sun's expansion, and could even have habitable conditions for 100 million years or so.

Earth

The Sun's loss of mass will send Earth's orbit spiralling outwards, but then tidal effects will draw it back, ensuring that our planet is burnt to a cinder in the Sun's outer layers.

Venus

The Sun's increasing brightness will blast away Venus' thick atmosphere before swallowing up the planet itself.

Mercury

If Mercury's orbit remains stable until the Sun's red giant phase, the innermost planet is sure to be swallowed up by the expanding star.

The Sun's evolution to a black dwarf

The long-term fate of the Solar System is governed by the star found at its centre. Fortunately we have several billion years before the Sun goes through any major changes

Ageing Sun

As our star uses up the hydrogen fuel in its core, it brightens slowly over the next 5 billion years.



Growing giant

As hydrogen fusion moves into shells around the core the Sun brightens and swells in size, with its surface growing cooler.

Monster star

At its greatest extent the Sun will probably have a diameter equivalent to Earth's current orbit.

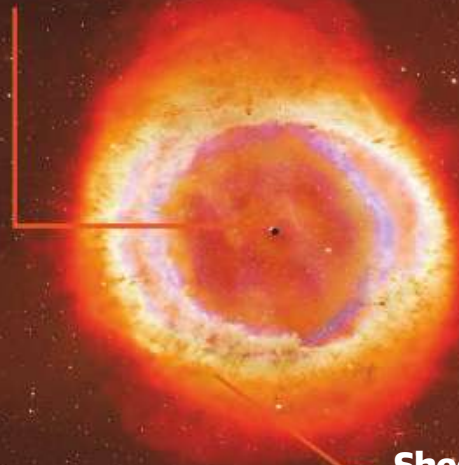


Unstable phase

After a brief respite as the core reignites and fuses helium, the Sun swells again, entering a period of pulsations in brightness and size.

White dwarf remnant

Eventually the Sun's core is exposed as an incandescent, slowly cooling white dwarf star. Over billions of years this fades away to become a cold black dwarf.



Black dwarf

Due to the time it takes for them to evolve, a black dwarf has never been observed.



Shedding layers

The Sun becomes ever more unstable and its outer layers are blown off to form a spectacular but short-lived planetary nebula.

© Tobias Roetsch



Left: In about 500 million years from now the Moon's slow drift away from Earth will mean it can no longer cover the Sun's disc in a total solar eclipse

Due to the Sun's weakening gravity, the orbits of the planets will spiral outwards. The effect won't be enough to save Mercury or Venus if they are still near their current orbits, but it might be enough to save Earth - if not for another twist in the tale.

"As the Sun expands and loses mass, its rotation rate slows down," says Smith. "By the time it is 200-times larger than its current radius, its rotation period will be 2,500 years instead of one month. For Earth this has a drastic consequence: as it orbits past a Sun whose surface is now rather close, it raises a tidal bulge on the Sun's surface. As it moves ahead of the bulge, this exerts a tidal drag on Earth, causing it to lose energy and spiral in towards the Sun. Interaction with the Sun's outermost atmosphere introduces a further drag force - the combined effect of these two forces is enough to cause a fatal spiral into the Sun, and the vaporisation of Earth."

Earth, it seems, is doomed by a very similar effect to that which is currently pulling Phobos to its fate. But what would be the effect of these dramatic changes further out in the Solar System? "The increased luminosity of the Sun means that all the planets also heat up, with some of them becoming potentially habitable," explains Smith.

“There is a habitable zone in the Solar System in the form of a ring, which currently only includes Earth near its inner edge. As the Sun brightens the habitable zone will expand, leaving Earth behind in about 1 billion years. Unfortunately the habitable zone moves rather slowly for most of the Sun’s red giant evolution, speeding up only in the last half-billion years before helium ignition. This means that Mars, for example, will only enter the habitable zone 6 billion years after Earth leaves it, and will stay in it for 100 million years.”

Such periods are far too short for any life to evolve and take advantage of them, and before the habitable zone can reach the outer edge of the Solar System, the Sun will undergo another dramatic change. An event called the helium flash will see the core reignite, fusing helium into heavier elements. As its internal structure changes, our star will become much less luminous and shrink back rapidly, taking the habitable zone with it. Helium burning may last for about 100 million years before the core’s supply of that fuel is also exhausted. After swelling to a red giant once again, the Sun will become unstable, discarding its outer layers in a small planetary nebula and ultimately leaving behind just the burnt-out, incandescently hot planet-sized core – a white dwarf.

Is that the end for our Solar System? Remarkably, recent work by astronomers at the University of Hawaii suggests it might not be. Ben J. Fulton and

his colleagues investigated the possibility that new planets might form in the aftermath of the Sun’s burnout, and asked whether they might be able to support life. “The idea is that the remains of these destroyed first-generation planets might be able to re-coalesce into a second generation of planets once the star runs out of hydrogen and helium and contracts into a white dwarf,” explains Fulton. The small size of the Sun’s white dwarf remnant would make it far fainter than the present-day Sun and would mean that any habitable planets would need to orbit much closer in.

“White dwarfs are like hot embers left after a fire goes out,” continues Fulton. “They start out bright and hot and slowly cool for the rest of eternity. This means that the orbital radius of the habitable zone around a white dwarf evolves with time. Just after the formation of the white dwarf the habitable zone is relatively far away and evolving very rapidly, but as the white dwarf ages the distance to the habitable zone moves inward and the evolution

slows down. A planet orbiting at a distance of 0.01 AU will be within the habitable zone for 8 billion years from about 2 billion years after the formation of the white dwarf.”

Compared to ‘normal’ exoplanet systems, such white dwarf planets might be rarer. Fulton and his colleagues carried out a survey and found that ‘super-Earths’ are expected in the habitable zones of seven per cent of white dwarfs. That is in contrast to estimates of 15 to 20 per cent for super-Earth planets around Sun-like stars, but there are billions of white dwarfs out there. “Our survey was not sensitive to smaller planets or asteroidal debris, which have recently been discovered around a white dwarf,” admits Fulton. “It’s possible that these smaller planets commonly orbit white dwarfs throughout the galaxy.” Even if the Solar System as we know it is doomed to die when the Sun expands into a red giant in 7 billion years’ time, it’s comforting to imagine a new system of strange planets orbiting our burnt-out star in the future.

“EARTH, IT SEEMS, IS DOOMED BY A VERY SIMILAR EFFECT TO THAT WHICH IS CURRENTLY PULLING MARS’ MOON PHOBOS TO ITS FATE”

Colonising the Solar System

Earth has a few billion years left before the brightening Sun makes its surface uninhabitable, so where could we go next?



The Moon

2050

-180°C to 120°C (-292°F to 248°F)

Pressurised environment

No atmosphere – however, this means that environmental conditions on the Moon will change less dramatically than they will back here on Earth.



Mars

2100

-55°C (-67°F)

Pressurised environment or terraformed planet

Carbon dioxide – but planetary engineering could trigger a greenhouse effect and release trapped ice, warming the planet to produce breathable air.



Callisto

2200

-140°C (-220°F)

Pressurised environment

None. Callisto would remain too cold to terraform until the Sun enters its red giant phase, but is the safest of all Jupiter’s moons in terms of radiation risk.



Titan

2300

-180°C (-292°F)

Pressurised environment

Nitrogen and methane – although it will remain deep frozen for billions of years, Titan has a thick atmosphere and many resources to support a human colony.

YEAR LIKELY TO HAPPEN

TEMPERATURE AT TIME OF COLONISATION

TYPE OF HABITAT

ATMOSPHERIC CONSTITUENTS AT TIME OF COLONISATION

© NASA

21

SATELLITE REPAIR DROIDS

What to do when an outer space satellite breaks down? Send in the robots!

Droids could soon be placed on satellites in geostationary orbit (GEO) around Earth to make the job of repairing and maintaining them much easier - and cheaper.

The Defense Advanced Research Projects Agency (DARPA) is looking at the possibility of installing robots on satellites before they are launched into orbit. Once on board the droids would be responsible for a number of tasks, including inspecting the satellites, fixing any problems and performing orbit adjustments.

This project, named Phoenix, would slash the cost of dealing with problems of satellites that orbit at a distance of 35,400 kilometres (22,000 miles) above Earth. Satellites operating in a low-Earth orbit (LEO) are able to be repaired by conventional means because they are within easy reach of Earth, but the height of the geostationary satellites means that any repair missions are impossible with current technology. Establishing a droid on a satellite before launch would enable scientists on Earth to affect a remote repair. This would increase the life expectancy of the satellites, as damaged satellites could be repaired rather than ditched.

DARPA is asking for assistance in developing the technology, having already completed Phase 1 of the Phoenix project, which was a feasibility study into what actions the droids could perform in space. Phase 2 will be the development of three main areas of technology. The first is droids that can repair satellites, using robotic arms to carry out tasks. The second is the development of satlets, which are modular satellite architecture that can carry out similar roles to satellites. The final technology being developed as part of the Phoenix project is a Payload Orbital Delivery (POD) system, which is a mechanism that can carry essential items

Lightweight

The droid will be significantly smaller and lighter than the satellite. Although this does add weight to the launch, it improves efficiency overall.

On-board repairs

The droid will be sent up with the satellite as part of its payload to ensure it is there when it is needed.

Inspection

Part of the droid's role will be to inspect the satellite for any physical or technological damage. This will give an accurate reading of the required procedures.

Private and public

This technology would be designed to be used on both private and military satellites, which is why DARPA is asking for outside help.

Adjustments

The droid will be able to move the satellite when it comes to the end of its service to make room for further missions in geostationary orbit.

Inside the satellite

It will be able to perform its task by manipulating the electrical systems inside the satellite, rather than physically moving it.

Mechanic

It will also act as an on-board mechanic, correcting mechanical and physical problems in situ. This will be the first time satellites in GEO could be repaired in space.

Toolbox

They will have robotic arms to perform the repairs as well as a supply of spare parts that can replace any faulty or damaged sections of the satellite.

into space along with the satellite. These three areas are being looked at by a number of private companies, who will construct models and report back to DARPA with their findings.

The GEO satellites need to be that far away from Earth because that is the distance at which they are able to be in geosynchronous orbit with the planet. This is where the satellite orbits at the same time as Earth spins, so it is always over the same point. There are currently over 900 satellites in GEO over the equator, which is another important role that the droids could perform. The space around the equator is becoming crowded, so at the end of their life

cycle the droid could shift the satellite's orbit, which would allow another satellite to take its place and reduce the risk of a collision.

As more and more satellites are being launched every year, the need for a reliable and comparatively cheap method of repairing them is becoming increasingly important. This project from DARPA could potentially be extremely important, as it could massively reduce the cost of repairing satellites. If the technology behind the Phoenix project is successful, it could be rolled out to other spacecraft and probes, extending their lives and enabling us to explore even further reaches of the galaxy.

Destination: Alpha Centauri

DESTINATION ALPHA CENTAURI

Some of the world's top scientists are
looking to reach for our nearest stars

Reported by David Crookes

If you gaze into the night sky from Earth's Southern Hemisphere, you should be able to catch sight of our nearest stellar neighbour, Alpha Centauri. It appears to the naked eye as a single, brightly glowing celestial object and has long been a source of fascination for astronomers.

Alpha Centauri was discovered to be a binary star system in 1689, made up of Alpha Centauri A and Alpha Centauri B, and in 1915 a fainter star called Proxima Centauri was observed relatively close by. However, there has been some doubt cast over more recent theories about the star system. In October 2012 a team of European observers claimed to have evidence of an exoplanet orbiting Alpha Centauri B, and yet, almost exactly three years later, the theory was dismissed by a group of astronomers at Oxford University. Other theories relating to exoplanets within the star system are similarly up in the air.

The key issue with Alpha Centauri is that it is 4.37 light years away, and while Proxima Centauri is closer, it is still distant by a just-as-daunting 4.24 light years. Travelling to the star system would entail a journey of some 40 trillion kilometres (25 trillion miles), and with current spacecraft speeds, like NASA's Parker Solar Probe, you'd have to be travelling for more than 6,300 years to reach it. It's no surprise so few have seriously considered launching a craft that would, quite literally, reach for the stars. Yet that is just what a group of some of the world's most respected scientists and engineers are now hoping to do in their bid to vault into the interstellar age. Advances in technology, combined with the financial backing of Russian entrepreneur and physicist Yuri Milner, are set to place what was felt to be the impossible very much on the table of possibility. "The problem is, space travel as we know it is slow," says Milner. "If Voyager had left our planet when humans first left Africa, travelling at 18 kilometres (11 miles) per second, it would be arriving at Alpha Centauri just about now. How do we go faster and how do we go further? How do we make this next leap?"

In 2015 Milner and Stephen Hawking created the privately funded company, Breakthrough Initiatives. Almost immediately it launched a program called Breakthrough Listen, which heralded a cash-rich search for alien life beyond the Solar System. Now, with Facebook founder Mark Zuckerberg also on board, it has unveiled a new project: Breakthrough Starshot. Its aim is to develop a craft and propellant system capable of reaching Alpha Centauri just 20 years after launch.

The central idea of Starshot is to send a fleet of tiny probes called nanocrafts deep into the more remote regions of space. It would involve shooting a powerful laser beam to propel them to one-fifth of the speed of light. When they reach their destination the probes will be able to take photographs of the celestial bodies they encounter

"WITH THE LIGHTEST SPACECRAFT EVER BUILT, WE CAN LAUNCH A MISSION TO ALPHA CENTAURI WITHIN A GENERATION" **STEPHEN HAWKING**

and gather other scientific data before sending the information back down to Earth. The research and engineering program would enable many of today's scientists to search for extraterrestrial life, seek exoplanets and maybe even discover an Earth-like body in a habitable zone. It would also prove useful in quickly exploring planets and other bodies far closer to home. The potential is huge.

So why has this possibility only just emerged? The answer lies in many of our pockets: within our smartphones and tablets. Moore's law has meant that the size of microelectronic components has vastly decreased thanks to nanotechnology advances and the incredible demand for smaller, smarter consumer devices. If you pulled apart an iPhone and discarded the screen and casing, you would see that the basic driving force behind it is not only light in weight but small in size.

It's on this principle that the nanocrafts will be built. The so-called StarChip will be a small 'wafer' of around 25 millimetres (0.9 inches) in size and will weigh less than one gram (0.04 ounces). Yet it will be capable of carrying the key components of a robotic probe; that is a camera - or indeed four - power supply, thrusters and both navigation and communication equipment. They will be so tiny and eventually so relatively inexpensive to make that hundreds or maybe thousands of them are intended to be placed within a mothership and

Below: Some of the best individual brains in science, engineering and aerospace are working on the Breakthrough Starshot project



© Breakthrough Initiatives Group

Why should we go to Alpha Centauri?

British Astronomer Royal Martin Rees shares his thoughts on studying the system

Is there anything special about Alpha Centauri?

It's a binary star where the separation is about the distance between the Sun and Neptune. But I think for most astronomers it's the study of exoplanets that is especially interesting because that has only opened up in the last 10 or 20 years.

Why is there interest in Alpha Centauri?

Some of us want to study the stars and some of us want to get detailed images of planets around stars. The main scientific goal is to find Earth-like planets. We didn't know until five years ago that most stars have planets around them. That makes it more interesting.

Could the focus move away from Alpha Centauri once the Starshot project is ready to launch?

Long before we launch these probes, I suspect we'll have learned enough about all of the nearby stars to know which ones have the most interesting planets around them. Before it's possible to launch anything we would know if Alpha Centauri was the best target. We would have enough information to make that decision.



Destination Alpha Centauri

Alpha Centauri A

The fourth-brightest star that can be seen from Earth. It is 4.37 light years away and 1.1 times the mass of our Sun, but with a luminosity 1.52 times our own star's.

A third star

A faint red dwarf star called Proxima Centauri is our closest star – about 4.25 light years from the Sun.

Alpha Centauri B

The star is not alone. It is part of a binary star system that includes Alpha Centauri B – a star slightly smaller than our Sun but with half its luminosity and a lower temperature.

A discovered planet

A world called Proxima Centauri b was discovered by astronomers in August 2016, orbiting parent star Proxima Centauri. The aim is for Starshot's probes to perform a flyby.



rocketed into space. The sheer numbers will allow for a large margin of error, ensuring that at least some of them will succeed in reaching their target. It sounds throwaway, but having more than one device flung into space also opens up the possibility of having different instruments on different StarChips, widening the scope of the collectable data. In all of this, Breakthrough Initiatives says it is bringing "the Silicon Valley approach to space travel," and it is hard to argue against that.

But it's only part of the story. Although work has already begun in prototyping the miniaturisation of the spacecraft – notably by researcher and aerospace engineer Zac Manchester – the rest of the program hinges on having something that can not only create forward propulsion, but also get the probes to the desired speed. For this an extremely thin, one square metre (10.8 square foot) sail will open shortly after the nanocrafts have been launched from their mothership. The StarChips will then literally sail to their destination.

Using sails in space is not a new idea. Johannes Kepler wrote to Galileo about this very concept in 1610, and exactly 400 years later the Japanese spacecraft IKAROS became the first to successfully use a solar sail that unfolded slowly to an area of 32 square metres (344 square foot). Sails can take advantage of the Sun's wind to propel a spacecraft forward

with a push of photons. Indeed, so well-known is the power of photons that they were even used to balance the Kepler Space Telescope.

Here though, the idea begins to sound like it has been ripped from the pages of a science-fiction novel. The problem with relying on the Sun to produce the required force to propel the StarChip to one-fifth of the speed of light is that our star isn't forceful enough to do this, so the Starshot scientists are looking to use a powerful laser beam instead. The beam will shoot out towards the probes and hit their light sails with a torrent of photons. It is this that will cause them to accelerate to a blistering speed in the microgravity vacuum of space. Within two minutes the nanocrafts will be as far as 965,600 kilometres (600,000 miles) from home and well on their way to their target. "With light beams, light sails and the lightest spacecraft ever built, we can launch a mission to Alpha Centauri within a generation," said Professor Hawking.

That's not to say any of this will be straightforward. It could take a decade, maybe two, to even get the technology to a stage where a launch is actually possible. "It's a very complex program," Professor Philip Lubin of the University of California, Santa Barbara tells us. "You don't want to go into this assuming everything is simple because it's not. We know how to do many of the things, but there are many things we don't. Some will require development over years, which is why we're

Who's involved?

The Breakthrough Starshot project has some of the best and most influential figures from science, engineering and aerospace working on the spacecraft that will reach further than ever before



© Getty

Stephen Hawking

Former director of research at the University of Cambridge

Notable achievements: One of the greatest scientists of all time, he helped to advance the Big Bang theory. His well-known book *A Brief History of Time* has sold over 10 million copies.

Involvement in Project Starshot: Former board member of Breakthrough Initiatives.
"Sooner or later, we must look to the stars. Starshot is an exciting first step on that journey."



© Breakthrough Initiatives Group

Yuri Milner

Founder of DST Global

Notable achievements: The Russian entrepreneur and physicist has invested in numerous tech businesses such as Facebook, Twitter and Spotify.

Involvement in Project Starshot: Funding Breakthrough Initiatives.
"The human story is one of great leaps - 55 years ago, Yuri Gagarin became the first human in space. Today we are preparing for the next great leap - to the stars."



© Breakthrough Initiatives Group

Ann Druyan

Author, producer and specialist in science communication

Notable achievements: Selected the music included with Voyager 1 and 2, co-writer of the 1980 PBS documentary series *Cosmos* and producer and writer of *Cosmos: A Spacetime Odyssey*.

Involvement in Project Starshot: Member of the Breakthrough Starshot Management and Advisory Committee.
"This kind of thinking that looks at a horizon 20, 35 or 50 years away is exactly what is called for now."



Source: Wikipedia Commons © JD Lasica

Mark Zuckerberg

Founder and CEO of Facebook

Notable achievements: Creation of the world's largest online social network.

Involvement in Project Starshot: Board member of Breakthrough Initiatives.
"Our nearest star, Alpha Centauri, is 4.3 light years or about 25 trillion miles [40 trillion kilometres] away. Even with today's fastest spacecraft, it would take 6,300 years to get there. That's too long."



© Breakthrough Initiatives Group

Avi Loeb

Professor of science at Harvard University

Notable achievements: Author of over 700 scientific papers and four astrophysics and cosmology books. One of the 25 most influential people in space according to *TIME* magazine.

Involvement in Project Starshot: Chairman of the Breakthrough Starshot Advisory Committee.
"There is a big difference between physically exploring space regions and looking at them from a distance."



© Breakthrough Initiatives Group

Mae Jemison

Principal of the 100 Year Starship organisation

Notable achievements: Former NASA astronaut who flew on board Space Shuttle Endeavour in September 1992.

Involvement in Project Starshot: Member of the Breakthrough Starshot Management and Advisory Committee.
"Collectively we are, as humans, at a point in which technologically there is at least one feasible path to getting us to another star within our generation."



© AIAA

Zac Manchester

Researcher and aerospace engineer; founder of KickSat project

Notable achievements: A graduate researcher in aerospace engineering at Cornell University with a number of scientific interests. He also created the world's smallest satellite.

Involvement in Project Starshot: Assisting on prototype StarChip.
"Moore's law is making the sensors, tiny computers, radios and all the components we need to build the spacecraft available."



© Breakthrough Initiatives Group

Philip Lubin

Professor of physics at the University of California

Notable achievements: His scientific paper *A Roadmap To Interstellar Flight* details the feasibility of a gram-level spacecraft travelling at one-fifth of the speed of light.

Involvement in Project Starshot: Working on directed energy propulsion.
"Using the technology we're speaking about, we can get to Voyager, which has been travelling for over 42 years, in a day or so"



© Breakthrough Initiatives Group

Martin Rees

British Astronomer Royal

Notable achievements: Master of Trinity College, Cambridge, president of the Royal Society and cofounder of the Centre for the Study of Existential Risk.

Involvement in Project Starshot: Member of the Breakthrough Starshot Management and Advisory Committee and leader of Breakthrough Listen.
"We'd all like to find ET in our lifetime - it would be the greatest discovery of all time."



Source: Wikipedia Commons © Montoem

Freeman Dyson

Former professor emeritus at Princeton

Notable achievements: Known for his work in quantum electrodynamics, solid-state physics, astronomy and nuclear engineering.

Involvement in Project Starshot: Former member of Breakthrough Starshot's Management and Advisory Committee.
"This is part of the whole process of exploring the universe, which is something that we are pretty good at."



© NASA

Pete Worden

Executive director of Breakthrough Starshot

Notable achievements: Former director of NASA's Ames Research Center and author of more than 150 scientific papers.

Involvement in Project Starshot: Leading the Starshot program.
"We take inspiration from Vostok, Voyager, Apollo and the other great missions. It's time to open the era of interstellar flight, but we need to keep our feet on the ground too."

Destination: Alpha Centauri

Multiple launch

Hundreds or maybe thousands of StarChips will be sent into space at the same time by the launcher.

Sailing across the universe

The nanocrafts will carry a light sail measuring one metre squared (10.8 square feet) – large enough to capture the incoming laser beam.

THE LAUNCHER

How will we get there?

Since the StarChips are tiny, hundreds or maybe even thousands of them will be sent to the mission's target, providing ample cover for those that fail to make it for any reason. They will be packed inside a rocket-propelled orbiting mothership and released.

But here is where the true magic happens. Improvements in photonics will make it possible for phased arrays of lasers – each of which will be placed in a particularly arid Earth-based location such as the Atacama Desert – to fire a cumulative 100-gigawatt beam at the nanocrafts. This will propel them forward at speeds approaching one-fifth of the speed of light.

Lightweight

Both the StarChip and the light sail – which will be just a few hundred atoms thick and made of metamaterials – will weigh less than one gram (0.04 ounces).

Beam them up

Earth-based lasers create a single powerful beam that will point at the StarChips, accelerating them to 160.9 million kilometres (100 million miles) per hour.

THE LISTENER

How we'll communicate

According to Pete Worden, the executive director of Breakthrough Starshot, one of the major challenges is working out how the probes will be able to communicate with investigators on Earth.

Small lasers powered by a fraction of a watt could be carried on board the StarChip, and the light sail could be reconfigured as an optical element. The lasers would send out a signal and the Earth-based transmitting laser array would reverse their role, picking up on the communications. The images would take four years to be received.

going into a long-term development program." This part of the program relies heavily on advances in photonics, the science of light generation, detection and manipulation.

Lubin is at the forefront of this study, and it was he who detailed how photonics would play its part in spacecraft propulsion in a 66-page academic paper written in 2015 called *A Roadmap To Interstellar Flight*. The paper forms the basis of Starshot, and it says scientists and engineers need to fundamentally change their thinking of both propulsion and what a spacecraft is. It also says that changes in directed-energy technology mean that the idea of photon propulsion is no longer fantasy. The potential rewards are great.

Lubin points out that there is a rich environment to explore with more than 150 stars within 20 light years of the Sun. He says at least 17 of them appear capable of supporting planets that could contain life. But the scale of the task is immense. Rather than build a single laser, the idea is to create an array of phased light beams - numerous small lasers forming a single powerful light stretching more than 0.8 kilometres (0.5 miles). There are two reasons for this. First, to be effective the beam would ideally have to scale to 100 gigawatts and, as Lubin tells us, "we don't know how to make a single 100-gigawatt laser". Second, he continues, "even if we did there are reasons you wouldn't want to do that - you'd still need a beam director and a large area". For this reason, it makes sense to spread it out. "Even if someone handed you a 100-gigawatt laser that you could hold in your hand, you'd still need a large one-kilometre (0.6-mile) telescope to couple it to, because you have to form a spot at long distances with a large aperture," Lubin explains. Yet, he adds, "no one has ever built an array like that of this size, and there are a lot of issues relating to it which we will have to discover along the way."

But there are some clear benefits of using this system of propulsion. There would be no need for the nanocrafts to have fuel on board - which helps to keep them light - and the lasers can be recharged, whereas rocket fuel would be spent. Engineers would seek efficiencies, so steps would be taken to make optimum use of the laser beams, too: adaptive optics in the form of deformable mirrors would attempt to combat any atmospheric blurring caused by the dispersal of light, and the array would be positioned in a location to give it a better 'view' of the probes.

"There will be a large element in the first decade to work out a lot of the risk," Lubin continues. "And there will be a lot of political issues." Not to mention costs: "\$100 million (£81.2 million) will get us to prototype stage, but not to a system," he adds. Some figures suggest \$100 billion (£81.2 billion) will eventually be needed to see the program to fruition, and that could be a sticking point in the future. But there are some persuasive arguments for going

Reflective coating

It is important that the light sail is highly reflective so that it doesn't absorb the laser beams that are aimed at it. It may be used to focus communication signals from an antenna on the StarChip back to Earth.

The StarChip

The StarChip will be a thin slice of semiconductor material - or wafer - carrying four miniature two-megapixel cameras, photon thrusters and navigation and communication equipment.

Power point

The StarChip will also contain a power supply. At this stage, americium is being considered - an artificially produced yet slowly decaying radioisotope used in smoke detectors.

ACTUAL SIZE



© NASA

THE NANOCRAFT

What is StarChip?

THE JOURNEY

Space checkpoints

StarChip will hit several targets along the way

The Moon

Distance: 384,400 kilometres (238,855 miles)
Times around the world: 9.6



1 MIN

The Sun

Distance: 149.6 million kilometres (92.9 million miles)
Times around the world: 3,737



41 MINS

Mars

Distance: 54.5 million kilometres (33.9 million miles)
Times around the world: 1,361



1 HOUR

Pluto

Distance: 4.3 billion kilometres (2.6 billion miles)
Times around the world: 107,400



1 DAY

The Solar System's edge

Distance: 7.4 trillion kilometres (4.6 trillion miles)
Times around the world: 185 million



4 YEARS

Alpha Centauri

Distance: 40.2 trillion kilometres (25 trillion miles)
Times around the world: 1,004 million



20 YEARS

Need for speed

StarChip

Speed: 160.9 million kph (100 million mph)
Mass: Under one gram (0.04 ounces)
Time to edge of the Solar System:

Four years

New Horizons

Speed: 58,536kph (36,373mph)
Mass: 470 kilograms (1,036 pounds)
Time to edge of the Solar System:

Ten years



Voyager 1

Speed: 61,000kph (38,000mph)
Mass: 733 kilograms (1,616 pounds)
Time to edge of the Solar System:

35 years



ahead with it. As well as being able to boldly go where no human-made object has ventured before, the bonus of having such powerful lasers projecting into space - even for the mere minutes they'll actually be in operation - is that the light from the lasers will be detectable all across the universe. If intelligent life is out there, a civilisation may well spot it and respond.

Even so, some astronomers - including those heavily involved in the search for extraterrestrial life - do have their reservations. "I personally think that it's very ambitious, and I wouldn't bet high horses that it will ever be done," British cosmologist, astrophysicist and Astronomer Royal Martin Rees tells us. "All that has been done at the moment is to explore the feasibility of something that would cost many billions of dollars to actually do." Lord Rees questions whether the money might be better spent building huge telescopes in space, and he also raises two problems the Starshot team will be keen to resolve. "With the huge array you can send something to the nearest star in 20 years, but the probes can't slow down when they get there. They just fly past," he says. "This is a constraint, and I think that is something we have to clarify. The whole thing also weighs less than one gram (0.04 ounces) so how would it be able to transmit the data back?"

According to Pete Worden, who is directing the project, these issues will be addressed. The current thinking is that lasers could be fitted on board the probes to beam images back to the laser array, which could be turned into a receiver. But as Lord Rees says: "The Pluto flyby was slower and not nearly as far away, but it took a year to transmit

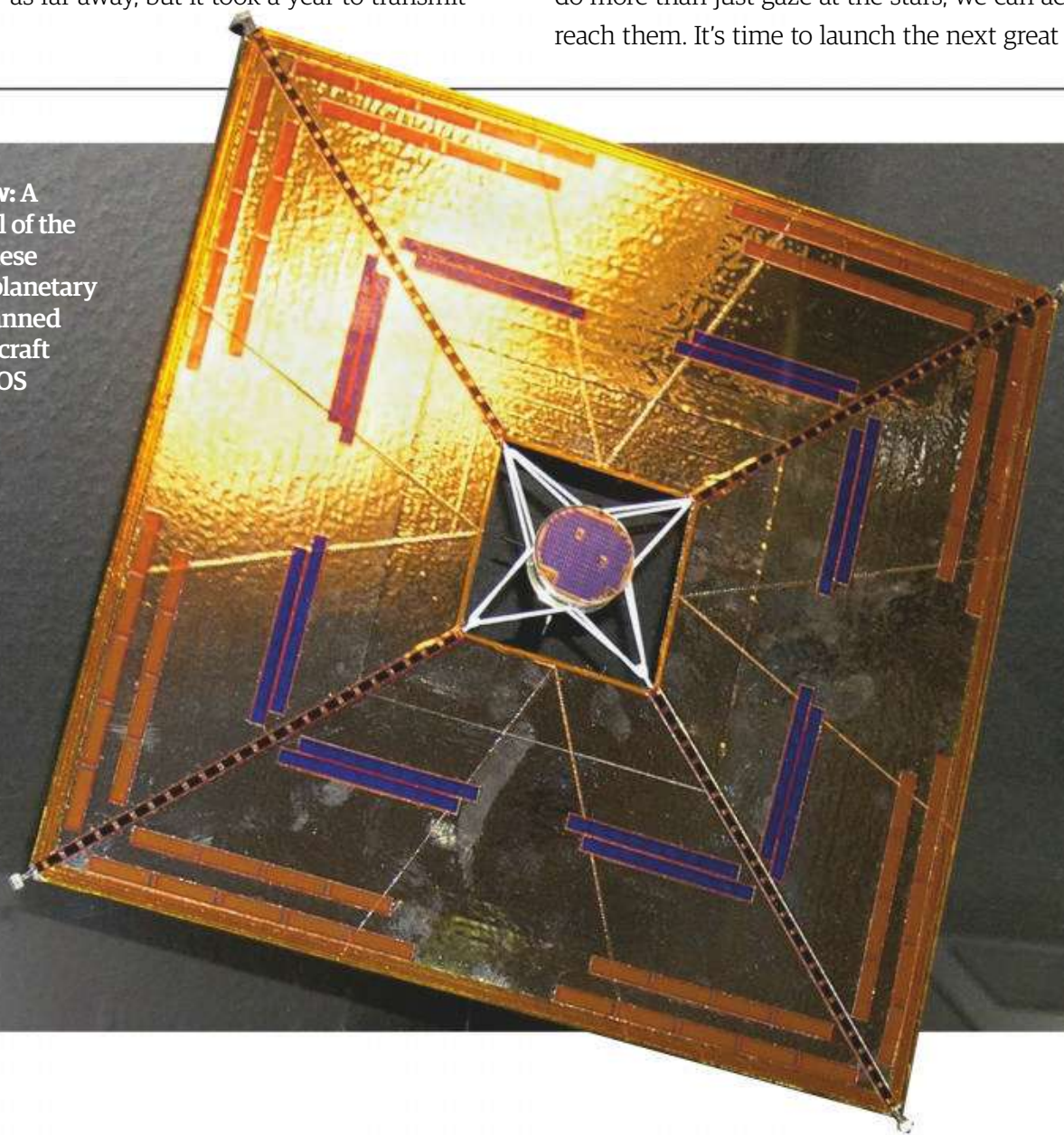
photos back. I would have thought that the issue of how good the pictures are and the rate of data transmission back, given a very low power, will pose a big challenge."

All of this, however, is why the project is likely to take so long to figure out, and the program is not looking to hide the challenges. It points out the risk of interstellar dust collisions, for instance, and highlights issues in focusing a light beam on the light sail to accelerate individual nanocrafts. At the same time, new technologies will emerge that enhance techniques in communication and optics and will be of wider benefit to the space industry.

But despite the challenges, the program appears in good hands. As well as having some of the best individual brains in science, engineering and aerospace on the job, universities and research centres are involved too. Breakthrough Starshot is also throwing the doors open to the public and will be encouraging scientific investment with research grants. The team wants the process to be open and transparent, and Breakthrough Initiatives is strictly non-profit. In the longer term Milner hopes to work with NASA and the ESA, both of which have been briefed and will inevitably look closely at the progress being made.

Ultimately it comes down to the mantra of nothing ventured, nothing gained. There are more benefits to be had in trying: "If this mission comes to fruition, it will tell us as much about ourselves as about Alpha Centauri," Milner says. "Only by challenging ourselves can we find out if we, like the pioneers before us, have the ability and ambition to succeed. For the first time in human history we can do more than just gaze at the stars, we can actually reach them. It's time to launch the next great leap."

Below: A model of the Japanese interplanetary unmanned spacecraft IKAROS



3 FREE DIGITAL BOOKS FOR EVERY READER!



60 SECOND SCIENCE

Welcome to **60 Second Science**. This fact-packed guide introduces fundamental principles in physics, biology and chemistry with clear, concise explanations, infographics and illustrations. From the Big Bang to quantum mechanics and from fossils to Wi-Fi, you'll be up to speed with the latest breakthroughs in no time. Throughout the book you'll also have the opportunity to put these theories into practice with some easy-to-follow experiments. See how circuits work with batteries made from lemons, detect Earth's magnetic field by making your own compass, learn how to instantly freeze water with a single touch and much more. What are you waiting for? Dive in to discover how the wonderful world around you works.

HOW IT WORKS BOOK OF SPACE

Space has fascinated humankind from the earliest days of civilisation, and as we keep scratching the surface of the vast universe in which we live, our sense of awe and wonder continues to grow unabated. Now, with the technological advancements being made by the world's space agencies, we understand more than ever about the things that are happening beyond our own planet. This new edition of the **How It Works Book of Space** has been updated with more of the latest astronomical advancements, stunning space photography from the most advanced telescopes on the planet and glimpses at what the future of space exploration holds, taking you from the heart of our Solar System and out into deep space.

SAVE THE WORLD

We're on the precipice of destroying our home planet forever, and action needs to be taken to save it - even on a small scale. Use the information in this interactive journal to identify areas in your life where you can make more eco-friendly choices, and track your habits with our interactive spreads. It's a statistical miracle that Earth has maintained its habitability in order to accommodate life for billions of years, so it's worth seeing what you can do to keep the planet this way for a while longer. Throughout the book you'll also notice 11 'myths' - these pages bust common misconceptions about climate change and reveal the truth behind these lies. Bear these in mind in the future - you never know when you'll have to correct someone!

DOWNLOAD YOURS NOW AT: WWW.SURVEYMONKEY.CO.UK/R/TMP2KVL

Could the Higgs destroy us?

THE HIGGS BOSON

COULD IT
DESTROY THE
UNIVERSE?

COULD THE GOD PARTICLE CAUSE SPACE AND TIME TO COLLAPSE, AS SUPPOSEDLY QUOTED BY STEPHEN HAWKING?

Reported by Kulvinder Singh Chadha

The universe could collapse into oblivion at any moment, the culprit being related to a recently discovered particle. The Higgs particle, known as the Higgs boson, was discovered in 2012 by the ATLAS and CMS detectors - A Toroidal LHC ApparatuS and the Compact Muon Solenoid respectively - of the Large Hadron Collider (LHC). The LHC is a huge particle accelerator, 27 kilometres (16.7 miles) in circumference, located underground at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland.

The existence of the Higgs particle was first predicted by a group of scientists including Peter Higgs, who won a Nobel Prize for the discovery alongside François Englert in 2013. They used the Standard Model to make their prediction, which scientists have been using as a guide to the discovery of new particles since the 1960s. The Higgs was included in those early days, but very few thought that it could ever be found.

The Higgs field gives matter particles - and also the Higgs boson - mass. However, scientists were somewhat torn on the discovery of the Higgs boson.

Big Bang

0.00 seconds

Widely considered to be the beginning of our universe. This point contains all of time and space, all of the universe's fundamental forces and is made of pure energy.

Inflation

10^{-38} seconds

A brief and rapid period of expansion of the universe begins, thought to be a consequence of the strong nuclear force becoming distinct.

Quarks and hadrons

10^{-10} seconds

The expanding universe cools enough for fundamental matter particles to form. These will combine into protons and neutrons as the universe nears its first second of existence.

Could the Higgs destroy us?

Many were astounded and elated by it, while others were somewhat disappointed that the Standard Model didn't turn up something more unexpected and interesting. However, it turns out that the Higgs may be exciting enough.

One of the most famous scientists in the world, the late, great Stephen Hawking, purportedly suggested that the Higgs particle would eventually destroy the universe and everything in it, although others previously made similar claims. However, Hawking's supposed claim garnered wide publicity in 2014 in the mainstream media and largely went unquestioned. Except that this was a misquote and was based on a subtle but important scientific misunderstanding.

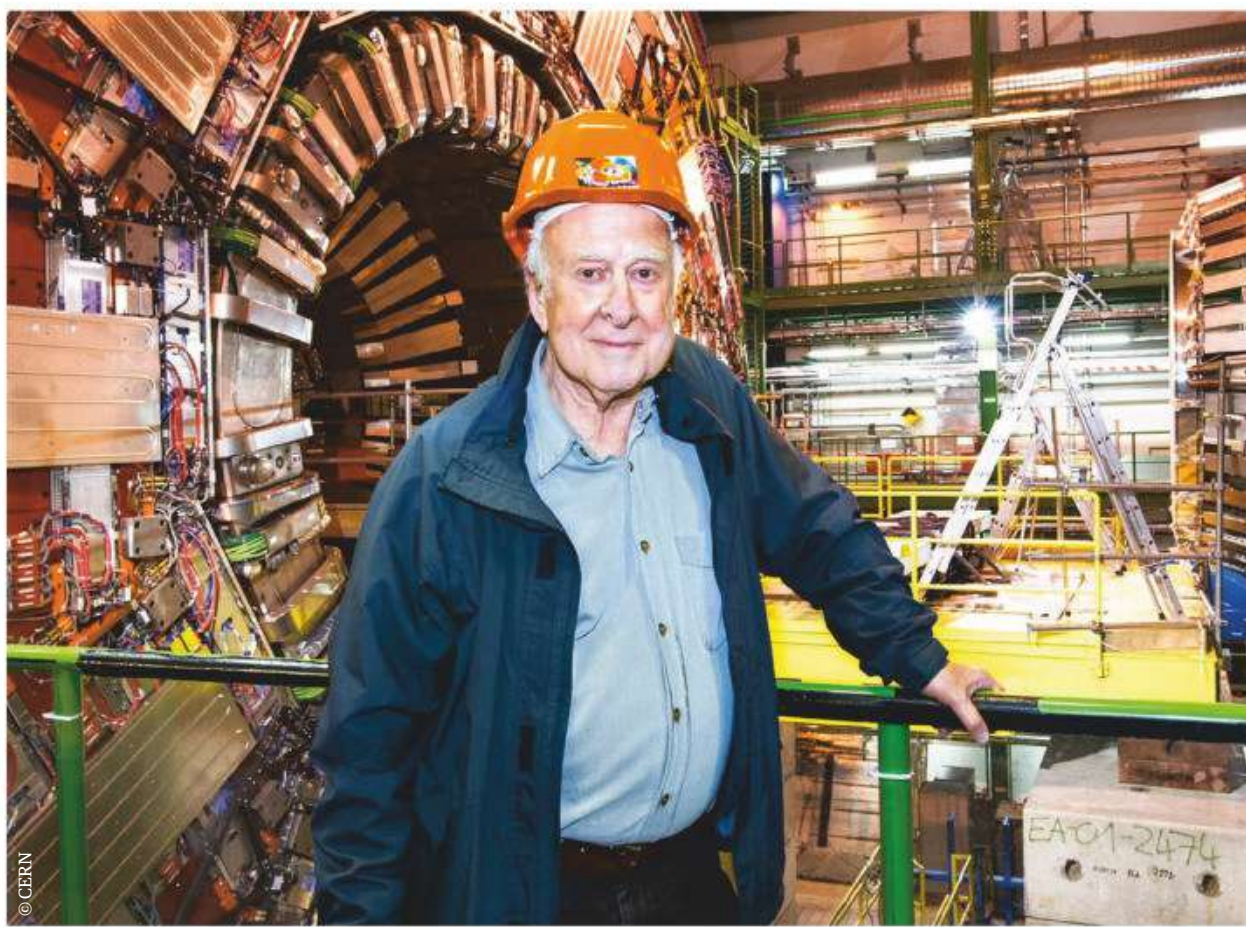
From the Starmus Festival in Tenerife, Hawking explained: "The Higgs potential has the worrisome feature that it might become metastable at energies above 100 [billion] gigaelectronvolts (GeV). This means that the universe could undergo catastrophic vacuum decay, with a bubble of the true vacuum expanding at the speed of light. This could happen at any time and we wouldn't see it coming." Although this sounds frightening, it is actually different from what media reported Hawking had said back in 2014.

Gigaelectronvolts and megaelectronvolts (MeV) are how particle physicists quantify the masses of subatomic particles. As an example, the proton would be around one GeV in mass, and the Higgs boson is about 125 GeV. Hawking was talking about the Higgs field - which permeates all of space - and not the Higgs particle, which is related, but different. Imagine an electron and an electric field; two things that are clearly related, but different. Catastrophic vacuum decay means that the universe may not be in its true 'ground' state and may be about to collapse at any time. Although Hawking didn't mention the Higgs particle, he did mention the Higgs field and vacuum decay. So what exactly is this phenomenon he spoke of?

The vacuum of space isn't a true vacuum. The true vacuum would be the lowest energy state, and a universe permeated by a Higgs field may not be in that state. As an analogy, imagine that the true vacuum is like the bottom of a depression, where it isn't possible to go any lower. Now imagine that our universe is on a mound within this depression, with a danger of collapsing. It may appear to us that we are in the lowest state,

Right: Professor Peter Higgs, who the particle was named after, visits the CMS experiment in Switzerland

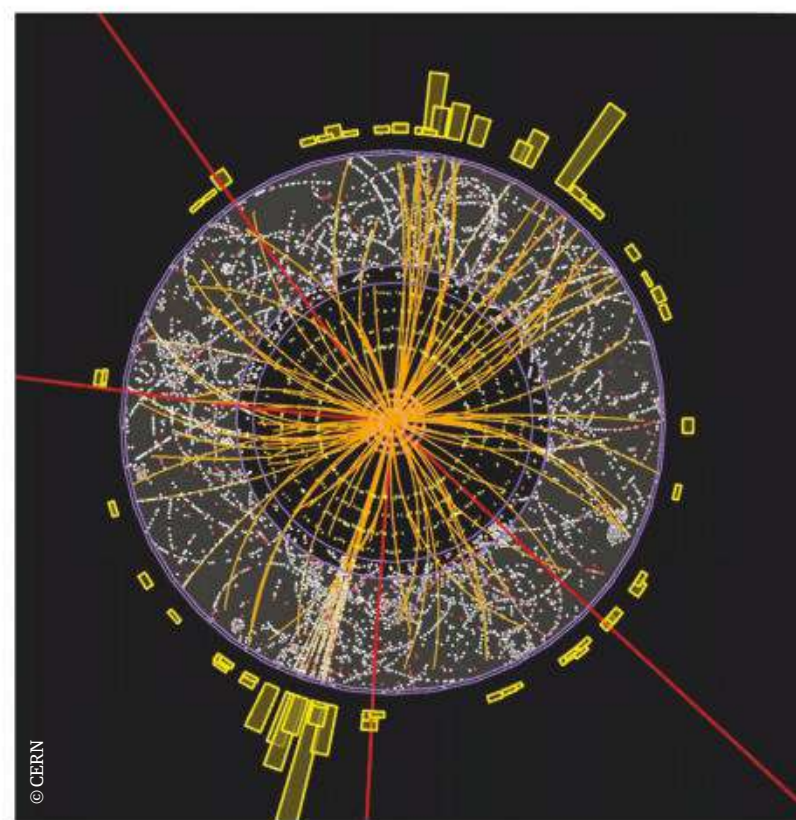
Below: The Higgs field is not the same as the Higgs boson, as some media suggested



"THE TRUE VACUUM WOULD BE THE LOWEST ENERGY STATE, AND A UNIVERSE PERMEATED BY A HIGGS FIELD MAY NOT BE IN THAT STATE"

but it wouldn't be the case. This is what the 'false vacuum' - which can seem like the true vacuum - means. Could our universe be on an unstable 'mound' with a danger of collapsing to a lower energy ground state? And would the Higgs field be responsible for that? Some scientists share Hawking's views on this.

Dr Joseph Lykken of Fermilab, Illinois, said at the 2013 meeting for the American Association for the Advancement of Science: "There's a calculation you can do in the Standard Model once you know the mass of the Higgs. If you use all the physics we know and do this straightforward calculation, it's bad news." He explains how the calculation shows how quantum fluctuations could be created; this could tip the vacuum into a lower energy state by creating bubbles. These bubbles travel at the speed of light and would cause the known universe



First nuclei

180 seconds

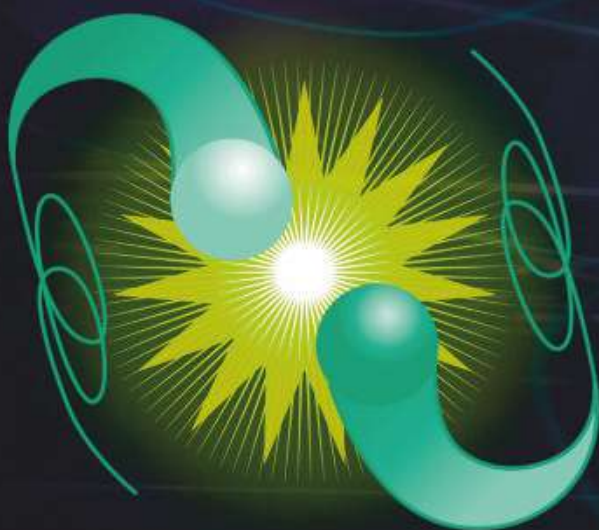
As the expanding universe cools further, the sea of protons and neutrons form atomic nuclei. Largely this is hydrogen and helium, possibly with some lithium.

What is the Higgs boson?

This particle was discovered in 2012 and mediates mass via an energy field

Finding hints of the Higgs

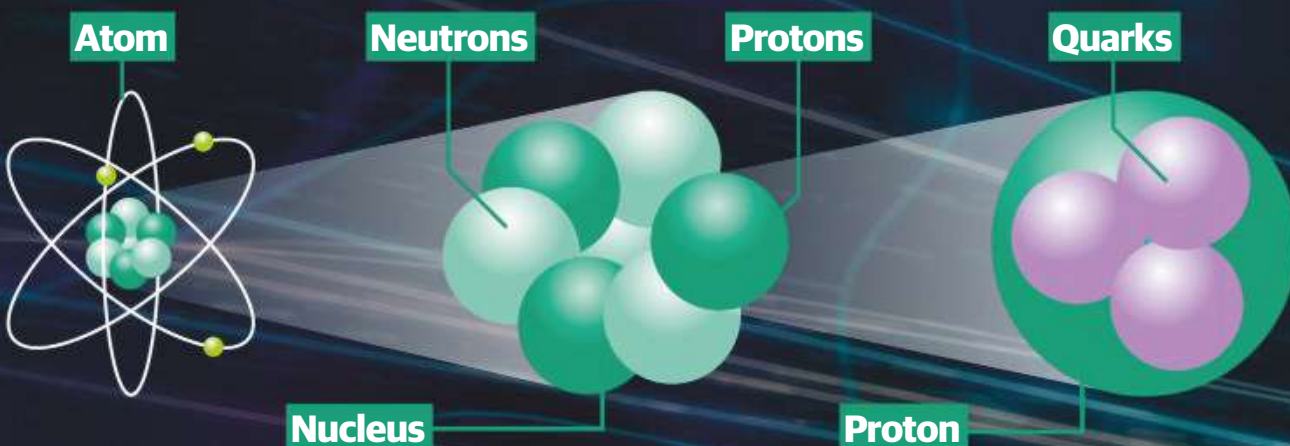
Was mass mediated by the Higgs boson? That's what the Large Hadron Collider tried to find out by using electromagnetic fields to whip beams of protons around and around to nearly the speed of light. When these protons collide, energy is released and new particles are made - which can provide evidence for the Higgs boson!



When particles collide, excess bosons or quarks may appear. How? They were formed from the Higgs boson.

Mass and matter

Matter particles, such as those that constitute atoms, contain mass. These particles come in two categories - quarks and leptons - while forces such as electromagnetism are carried by bosons.



Higgs compared to other particles

The mass of a particle is given in electronvolts, the energy an electron has when it's accelerated through one volt. The Higgs boson has a mass of about 125 billion electronvolts, while the photon has no mass.

Higgs boson
Mass: 125 billion electronvolts

Top quark
Mass: 170 billion electronvolts

Bottom quark
Mass: 4.2 billion electronvolts

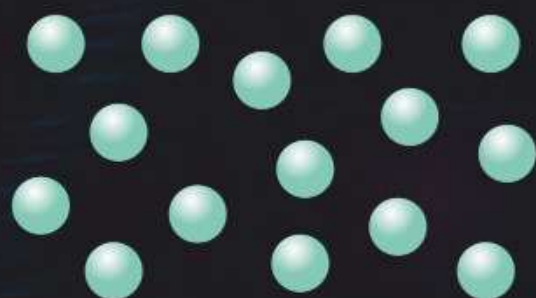
Proton
Mass: 938 million electronvolts

Electron
Mass: 0.5 million electronvolts

Neutron
Mass: 940 million electronvolts

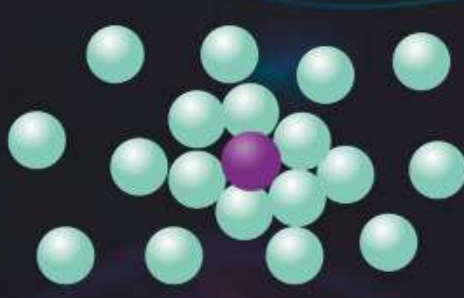
Higgs: why matter has mass

Particles may be more massive than one another because they feel the Higgs field differently. It's because of the Higgs boson that matter has mass.



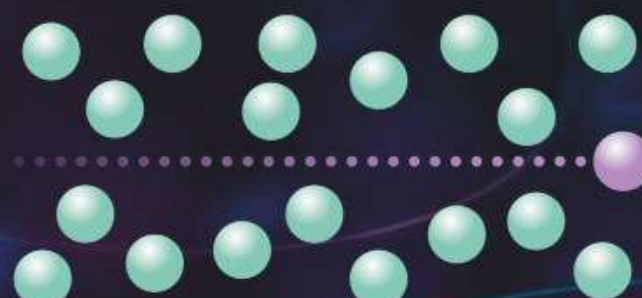
Meeting the Higgs field

The Higgs field occurs everywhere and gives matter particles mass. We can imagine the Higgs field as a group of evenly separated balls for this scenario.



Enter ordinary matter

When a particle of ordinary matter moves through the Higgs field, the field becomes excited and forms Higgs bosons, which cluster around the particle and provide it with mass.



High-speed photons

Particles can move through space without interacting with the Higgs field. They don't gain any mass from Higgs bosons and remain massless. A photon is one such particle.

First atoms

380,000 years

Free electrons combine with the hydrogen, helium and lithium nuclei to form atomic versions of the primordial elements. The dense 'fog' lifts as a result and the universe becomes transparent.

Dark Ages

380,000 to 300 million years

The universe remains dark for the next 299,620,000 years as primordial atomic hydrogen, helium and lithium atoms do nothing.

Understanding the Higgs and the universe's destruction

It took two detectors at the LHC to find the Higgs boson

4 Muon detectors

Detecting the charged particles known as muons is an important task for ATLAS. The muon is similar to an electron, but 200-times more massive. Decay into muons is one of the 'signatures' of the Higgs boson.

1 LHC

Accelerator ring

A large vacuum tube accelerates protons via powerful electromagnets to near-light speed.

2 ATLAS

Collision detector

With solenoid magnets and radiation trackers, ATLAS can detect different particles from beam collisions.

3 CMS

Compact Muon Solenoid

Using different technologies, the CMS confirmed ATLAS' detection of the Higgs boson.

5 Shielding

4

5

6

10

9

8

7

11

6 Hadronic calorimeters

The Hadron Calorimeter (HCAL) measures the energy of hadrons – particles made of quarks – and gluons, for example protons and neutrons.

7 Forward calorimeters

9 Inner detector

The first part of ATLAS to see the decay products of particle collisions. The inner detector is very compact and highly sensitive.

10 Solenoid

The ATLAS detector at CERN is equipped with a superconducting magnet. Its solenoid rests at the heart of the experiment, providing a field of two tesla.

11 Barrel toroid

ATLAS' barrel toroid consists of eight coils, each made of two flat superconducting double pancakes.

First stars

300 million years

Gravity eventually corrals the gaseous hydrogen and helium into galaxies and protostellar discs. These eventually collapse into the first stars.

Expansion accelerates

8.8 billion years

Since its inception the universe has been constantly expanding, but now it starts accelerating. The phenomenon behind this isn't known, but has been labelled 'dark energy'.

Present day

13.8 billion years

Several generations of stars have created complex elements in their cores, which have then scattered in supernovae explosions to create planets and life.

© NASA

Right:
Far into the future, star forming will cease, galaxies will die, and the Higgs may take over

“FOR SUCH A MASSIVE PARTICLE TO EXIST, THE HIGGS FIELD MUST POSSESS QUITE A LOT OF ENERGY”

to collapse into a lower energy state, effectively replacing it with another universe. As bizarre and scary as this sounds, Lykken reassures us that the chances of this happening are truly astronomical and depend on the particular cosmological epoch.

He says that if it does happen, most likely it'll take 10,100 years anyway, “so you probably shouldn't sell your house and [should] continue to pay your taxes”. By that time our Solar System and even our galaxy will be long gone, as all star-forming in the universe would stop and all of the stars would die out, leaving nothing but a dark void. Although there's nothing to worry about, the Higgs destroying the universe is still an extremely slim possibility. What's more, the universe could be complicit in this, but how?

When the universe began around 13.8 billion years ago – a figure that comes from NASA's Wilkinson Microwave Anisotropy Probe (WMAP) – it expanded and grew ever larger at a decelerating rate. This expansion continues to this day. However, observations from the late 1990s showed that this expansion started to accelerate around 5 billion years ago. Some powerful, unknown force, which actually makes up roughly 70 per cent of the energy density of the universe, is pushing space

apart. The nature of this phenomenon is unknown to us, but is called dark energy. This isn't really of any concern to us today, but imagine that far into the future the Higgs field starts to dominate an already-expanding universe and helps to destabilise it. Why should the Higgs behave like this at all?

With 125 GeV, the Higgs boson is a massive particle – much more so than the proton. For such a massive particle to exist, the Higgs field must possess a lot of energy. Einstein revealed in his paper on special relativity in 1905 that mass and energy are two sides of the same coin. This manifests itself in the famous equation $E=mc^2$. The Standard Model claims that massive particles are ‘metastable’, which means that they hover between stability and instability. According to Einstein's equation, related quantum fields would take a lot of energy to create particles of such mass. A change in the Higgs field could even change the mass of every particle in the universe, assuming they still existed in the future. “Then all the laws of physics change and everything is torn apart,” says Dr Tim Barklow of the SLAC National Accelerator Laboratory in California, and a member of the ATLAS team at the LHC. Does this mean we should be worried about the Higgs field after all?

Above:
NASA's WMAP spacecraft has used sensitive detectors in order to accurately measure the universe's age

Alexander Bednyakov of the Joint Institute of Nuclear Research, Russia, along with other scientists, carried out a detailed analysis in late 2015 using LHC data. They accounted for strong force interactions and other quantum corrections, revealing a painstaking body of work. They concluded that, as close as possible to the best theoretical fit, the universe is indeed in a metastable state. However, the values of the parameters they used are far closer to a region of absolute stability than what other previous studies suggested. It's important to remember that there are a few scenarios for the universe's eventual end: the Big Rip, the Big Freeze, the Big Crunch and the heat death of the universe. The Higgs is just another theoretical scenario – and one that many physicists say is highly unlikely to ever happen.

Expanding Sun

18.8 billion years

In 5 billion years the Sun will consume all of its hydrogen fuel and expand to become a red giant. In the process it will consume Mercury, Venus and Earth.

Star formation ends

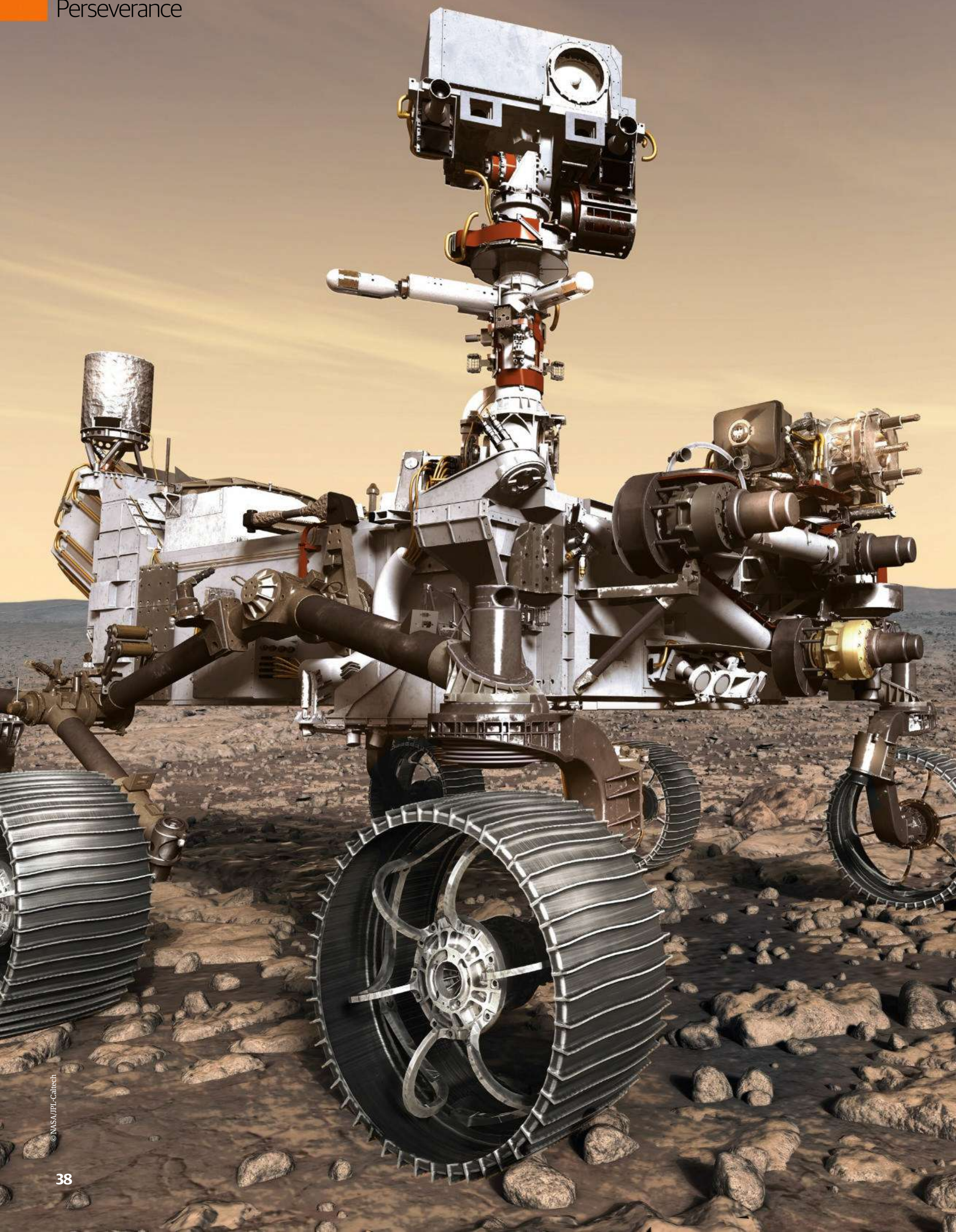
100 trillion years

All star formation ends about 100 trillion years after the Big Bang, and galaxies start to die out.

Higgs causes catastrophe

100 trillion or more years

The Higgs field causes a ‘catastrophic vacuum decay’, because the whole universe is inside a ‘false vacuum’ rather than the true one.



PREPARE FOR PERSEVERANCE

THE NEXT MARTIAN ROVER

Launching on 17 July, NASA's new craft will hunt for signs of past microbial life, cache rock and dig for soil samples - all while preparing for human exploration of the Red Planet

Reported by Lee Cavendish



Perseverance

© NASA/JPL-Caltech



M eet the new Martian rover from NASA, Perseverance. This next-generation explorer was built upon the successes of its predecessors Spirit, Opportunity and the Mars Science Laboratory (MSL), also known as Curiosity. All of these robot explorers have worked towards helping us better understand the planet next door, Mars, and in the wider scope of science understanding the past biology and geology of other worlds. Now the Mars 2020 mission's Perseverance rover is looking to go even further.

The launch date for this mission is scheduled for 17 July 2020, but the launch window will remain open until 5 August in case of setbacks. It will fly on top of an Atlas V 541 rocket, which also launched Curiosity and InSight, from Cape Canaveral Air Force Station in Florida. However, it won't be travelling alone. Alongside Perseverance will be a first-of-its-kind demonstration aircraft called the Mars Helicopter - more affectionately nicknamed Ingenuity. After launching the duo will spend over half a year voyaging through space to their destination, where the pair will hopefully land safely in Jezero crater on 18 February 2021. This is located on the western edge of Isidis Planitia, just north of the Martian equator.

After the much-fretted 'seven minutes of terror', where mission staff hold their breath for seven minutes as the rover goes through atmospheric entry, descent and landing, the rover will begin its primary mission duration of one Mars year - 687

days in Earth time. During this time Perseverance will inspect the Martian surface for signs of ancient life, characterise its geology and climate, prepare for future human exploration and collect samples of extraterrestrial rock for a future return mission.

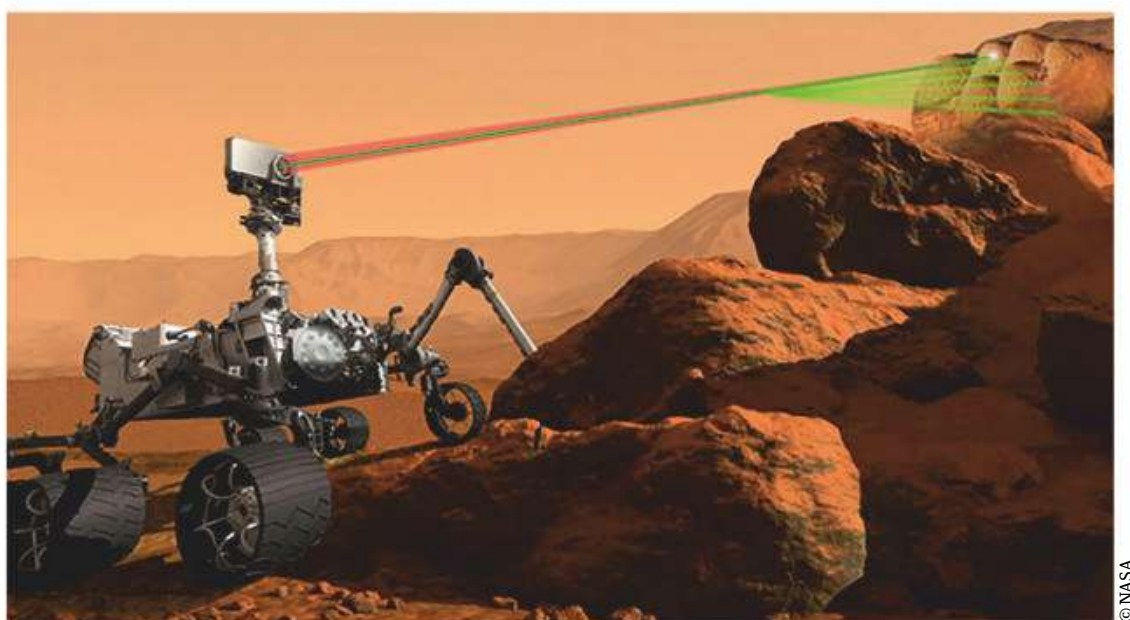
"Perseverance is the most sophisticated and complex rover mission we've ever sent to Mars. Perseverance has a new and updated science payload that makes it better suited for searching for ancient signs of life in the rock record of Mars than any previous Mars mission," explains one of the Mars 2020 deputy project scientists,

Dr Kathryn Stack Morgan. "Previous rovers have scratched, brushed and drilled Mars rocks before, but Perseverance is the first rover that will collect and cache intact rock samples. Perseverance's sample caching system and sample tubes were designed to ensure the scientific integrity of these samples for a potential future return to Earth, and the mission has met unprecedented requirements for biological cleanliness and contamination control to accomplish this."

"One of Mars 2020's key objectives is to collect and cache a set of samples that could be returned

Above: NASA's Mars Reconnaissance Orbiter has been watching over Jezero crater ahead of the rover's arrival

Right: The SuperCam will scrutinise the Red Planet's geology with unprecedented precision



© NASA

to Earth by a set of future missions. This concept is called Mars Sample Return, and it has been a goal in the planetary science community for a very long time,” explains Mars 2020’s other deputy project scientist, Dr Ken Williford. “There are many scientific and technical reasons to return samples from Mars, but one of the most exciting is the opportunity to use our most powerful laboratories on Earth to look for evidence of past life.”

This innovation would not have been possible without the help of the missions that came before.

The most obvious and recent example of this is Curiosity, and the two rovers share an almost-identical appearance. NASA has a habit of recycling space probe designs - for example, the currently operational InSight lander uses a design taken from the 2007 Phoenix lander. As the age-old saying goes: if it isn’t broken, don’t fix it.

When asked what the visual differences are between Perseverance and Curiosity, Morgan replies: “Perseverance has redesigned thicker and sturdier wheels compared to Curiosity, with

a different tread style, and it’s one of the most obvious visual differences between the two. The Perseverance turret at the end of the rover’s arm is also larger and heavier than Curiosity’s turret.”

It’s possible for more invested admirers to spot the differences, but to the untrained eye the updates are hard to take notice of. Morgan explains the advantages of using an essentially identical layout: “The use of build-to-print designs from the Curiosity rover and its landing system allowed Mars 2020 to focus its resources on the mission’s new elements and new technology.

“Perseverance has a new and updated science payload compared to Curiosity. The Mastcam-Z and SuperCam instruments build on heritage from Curiosity’s Mastcam and ChemCam instruments, but other Perseverance instruments - like PIXL and the SHERLOC spectrometer - are entirely new.

“PERSEVERANCE IS BETTER SUITED FOR SEARCHING FOR ANCIENT SIGNS OF LIFE THAN ANY PREVIOUS MARS MISSION” KATHRYN STACK MORGAN

Ingenuity: meet the Mars Helicopter

The success of this prototype could transform planetary exploration forever

Mass 1.8 kilograms (four pounds)	Rotor blade span Approximately 1.2 metres (four feet)	Length of mission One or more flights within 30 days	Propulsion method Counter-rotating blades that spin at about 2,400 revolutions per minute (rpm)	Key objective The first-ever technology demonstration of powered flight on Mars	Onboard equipment Navigation sensors, computers and two cameras: one colour and one black and white	Landing site Jezero crater - the helicopter will be in the belly of the Perseverance rover	Height Approximately 0.5 metres (19 inches)	Power system Purely solar-powered
---	--	--	---	---	---	--	---	---

© NASA/JPL-Caltech

Perseverance's instrumental suite

This investigative arsenal will reveal remarkable things about ancient Martian life and habitability

1 Mastcam-Z

Its objective is to take high-definition videos, panoramic colour and 3D images of Mars, with the added ability to zoom in on distant objects.

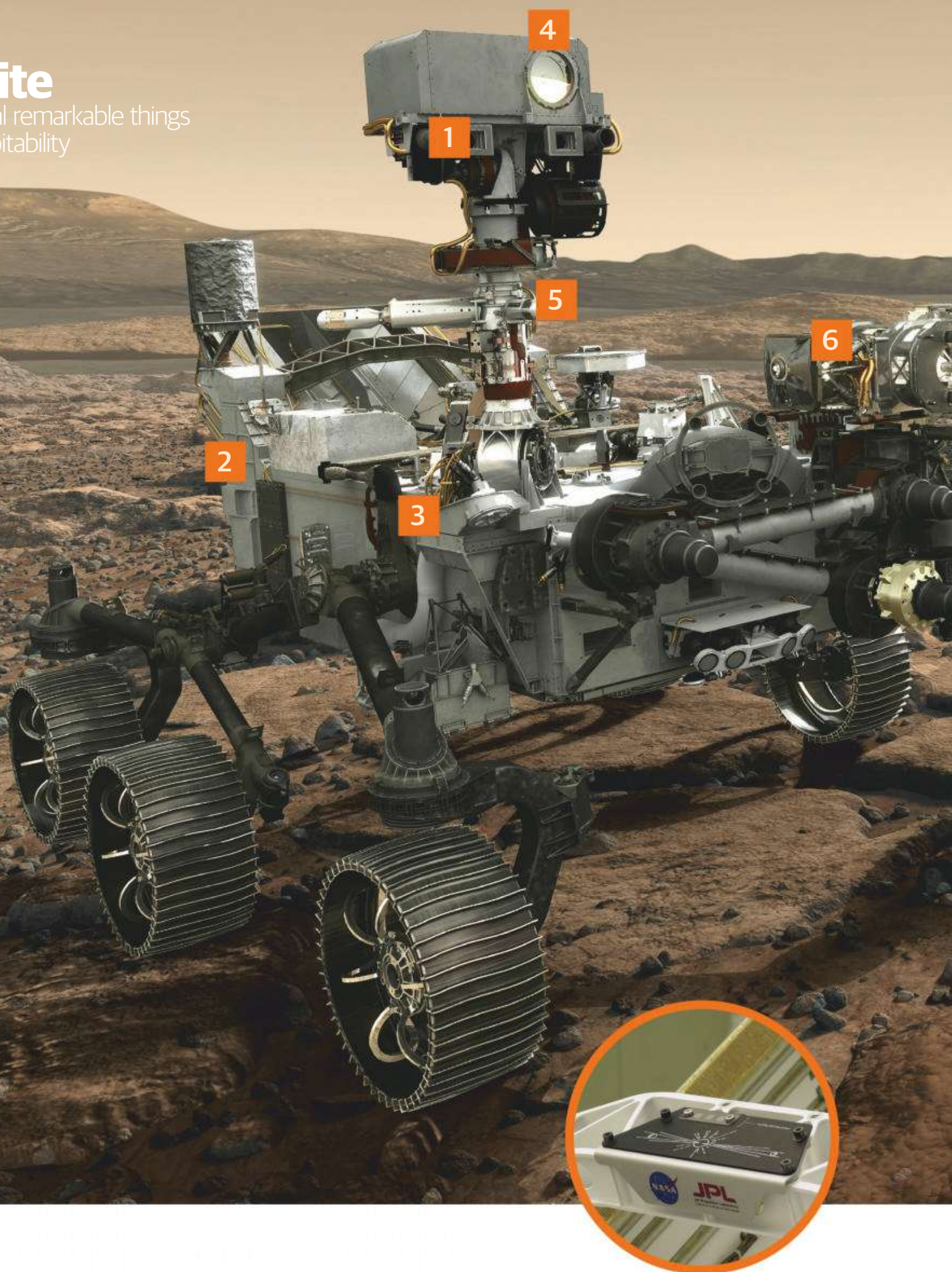
2 Radar Imager for Mars' subsurface experiment (RIMFAX)

Designed to see beneath the surface, RIMFAX will use ground-penetrating radar to detect underground geological features.

3 Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE)

This experiment will test if we can produce oxygen from Mars' carbon dioxide-rich atmosphere. This will have implications for the production of breathable oxygen and rocket propellant on other worlds.

x3 images © NASA/JPL-Caltech



Curiosity measures chemistry, mineralogy and the organic content of rock samples in a 'bulk' way from powdered drill fines. In contrast, Perseverance's PIXL and SHERLOC instruments allow us to produce detailed maps of chemistry, mineralogy, organics and texture without grinding up the rocks."

Seven new scientific instruments - including the aforementioned Planetary Instrument for X-ray Lithochemistry (PIXL), Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) spectrometer, SuperCam and Mastcam-Z - will explore the geology of the Jezero crater landing site, assess its

history of water and habitability, search for signs of past life and snap some more of those Mars selfies that everybody loves so much.

One experiment that will contribute to the Mars 2020 project, but will separate from the rover on arrival, is the Mars Helicopter. In April 2020 it was named 'Ingenuity' by a student from Tuscaloosa County High School in Northport, Alabama. It's purely a demonstration experiment. It is intended to become the first aircraft to execute powered flight on another planet, and if it works it will be a truly remarkable feat of engineering. Ingenuity will inform future innovative missions about flight

on Mars, where the gravity is roughly a third of the strength of Earth's. The atmospheric density at Mars' surface level is just one per cent of Earth's at sea level, so there have always been questions about how these alien conditions on Mars will alter aircraft flight performance.

"Rather than supporting Perseverance's science mission, the helicopter is meant to pave the way for future Mars exploration. Perseverance's cameras will be important to select a safe launch and landing area for the helicopter," says Williford. "If all goes well, we should be able to capture an exciting image of the helicopter in flight!"



4 SuperCam

SuperCam will search for signs of ancient life by analysing the chemical composition of rocks and soil, even to the degree it can identify their atomic and molecular make-up.

5 Mars Environmental Dynamics Analyzer (MEDA)

The local weather will be analysed with MEDA, including wind speed and direction, humidity, temperature and the dust in the atmosphere.

6 Planetary Instrument for X-ray Lithochemistry (PIXL)

PIXL includes an X-ray spectrometer that will identify the chemical elements residing in rocks in incredibly precise detail.

7 Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC)

Consisting of spectrometers, a laser and a camera, SHERLOC will search for minerals, organic molecules and potential biosignatures in Jezero crater.

Below: Perseverance's MOXIE and MEDA instruments will return valuable data for the future human exploration of Mars

With this outstanding arsenal of investigative apparatus the Mars 2020 mission will be well equipped to reveal the secrets of Jezero crater. But why this Martian site in particular?

"Jezero crater was chosen as the landing site for the Perseverance rover because it contains evidence of an ancient lake and delta that we believe was once habitable," says Morgan. "Delta and lake sediments on Earth are known to be great preservers of organic matter and evidence of life, and we hope that signs of ancient Martian life may be preserved in the rocks exposed in Jezero crater."

When looking back at the Mars Exploration Rovers, Spirit and Opportunity, and reminiscing about their journeys through Gusev crater and Meridiani Planum respectively, they both followed the water. Their main objective was to determine whether Mars was once a wet planet or not. Together they contributed pivotal evidence to the popular hypothesis that Mars had oceans, lakes and a warmer atmosphere over 3 billion years ago. A host of rovers and orbiters were fundamental in coming to this conclusion. The European Space Agency's Mars Express orbiter and NASA's Mars Reconnaissance Orbiter have even suggested water ice still exists at the planet's poles.

Now the Mars 2020 Perseverance rover is able to build upon this amazing legacy of discovery and focus on whether there was ever ancient life on Mars. It is generally agreed that a warm and wet planet is ideal for life as we know it to arise - which

"RATHER THAN SUPPORTING PERSEVERANCE, THE HELICOPTER IS MEANT TO PAVE THE WAY FOR FUTURE MARS EXPLORATION" KEN WILLIFORD



Mars once was. With Jezero crater, as a former lake and delta, being an excellent candidate to scrutinise, scientists may finally be able to answer the all-important question of whether there has ever been life elsewhere in the Solar System.

"If we see chemical elements, minerals and organic molecules that tend to be associated with life, and especially if we see these things arranged in spatial patterns that suggest biology, this could be evidence of ancient life on Mars," says Williford.

It could be the case that in the near future humans will be walking around on Mars. NASA and other global space agencies and private companies are currently looking to visit, inhabit and colonise the Red Planet. Although this will all happen in small stages over the next few decades, it is NASA's current intention to go back to the Moon by 2024 and then onward to Mars. Perseverance will assist in this dream of interplanetary exploration.

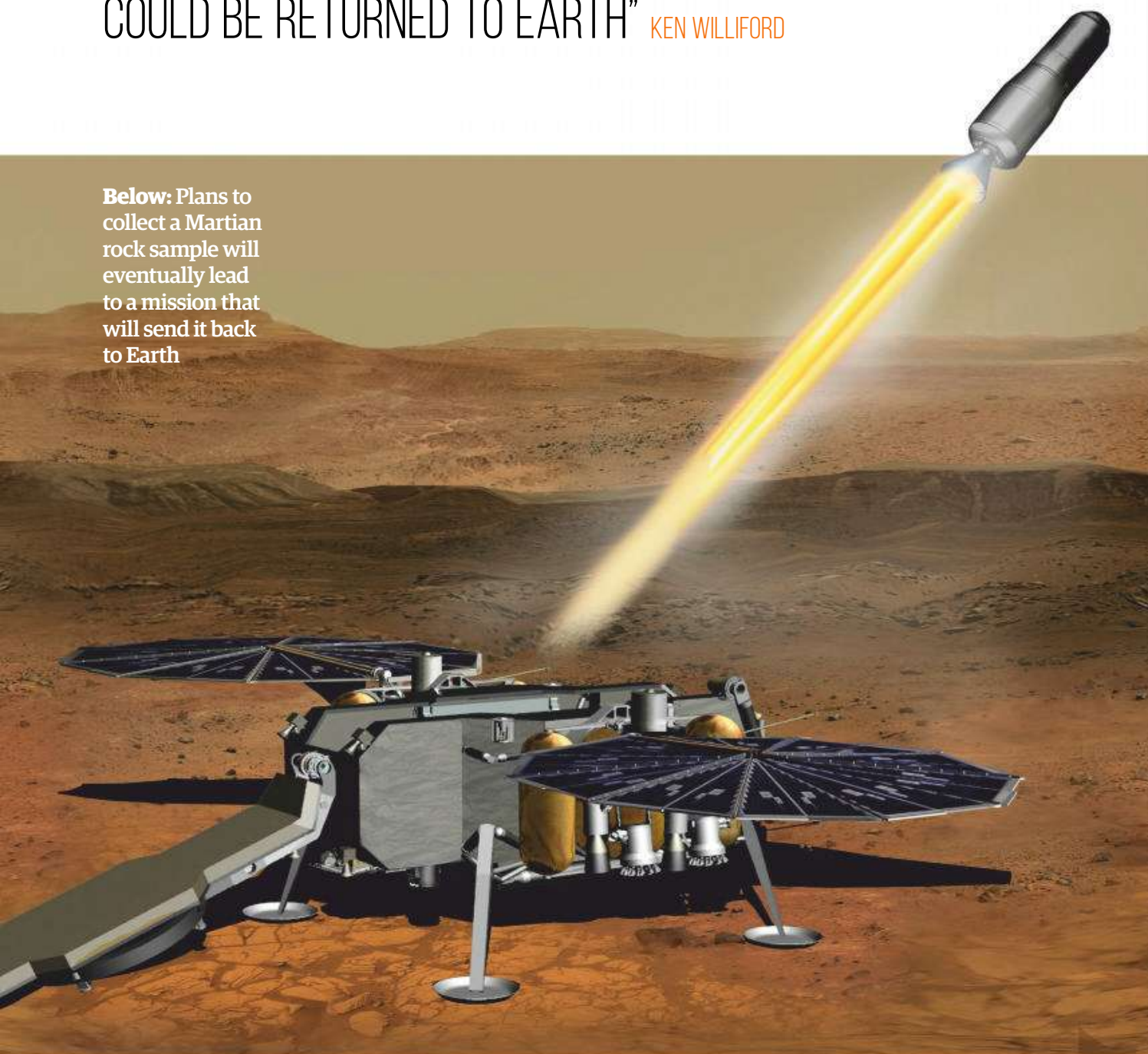
As Williford explains, Mars 2020 "has a weather station called MEDA that is contributed by Spain and will improve our understanding of surface conditions that astronauts would experience. We

have an instrument called MOXIE that takes in carbon dioxide from the Martian atmosphere and converts it to oxygen."

As seen with previous NASA missions, the public have once again been able to register to become a part of this endeavour. Similar to the space agency's past InSight and Parker Solar Probe mission launches, NASA created the 'Send Your Name To Mars' campaign, which has resulted in 10,932,295 people having their names stencilled onto three fingernail-sized silicon chips by electron beams. These three chips were attached to an anodised plate which also had a laser-etched graphic depicting Earth and Mars on either side of the Sun as it shines on both planets - akin to some depictions of the Golden Records sent aboard NASA's Voyager space probes. This remarkable rover bears the expectations of over 10 million people on its robotic shoulders, but if its predecessors are anything to go by, this mission will reap some groundbreaking results for many Earth years to come and will pioneer future missions to even greater heights.

"ONE OF MARS 2020'S KEY OBJECTIVES IS TO COLLECT AND CACHE A SET OF SAMPLES THAT COULD BE RETURNED TO EARTH" **KEN WILLIFORD**

Below: Plans to collect a Martian rock sample will eventually lead to a mission that will send it back to Earth



5 engineering facts as told by the team

This rover is different from the rest, and these are the five main reasons why

New wheels

Dr Kathryn Stack Morgan

"One of the biggest surprises early in Curiosity's mission was how much damage the rover's wheels accumulated from driving over the sharp, rocky terrain. To avoid any such problems, Perseverance has completely redesigned wheels that are thicker, stronger and better at climbing slopes."



Martian rock sample collection

Dr Ken Williford

"Mars 2020 will collect about 30 rock cores and soil samples, seal them in ultra-clean titanium tubes and deposit them in one or more collections on the surface. The future mission concept currently being studied jointly by NASA and the ESA would have two follow-on missions - one orbiter and one lander - launching as early as 2026."

Onboard microphones

Dr Kathryn Stack Morgan

"Another advance on Perseverance is the presence of several microphones. These microphones will allow us to hear the sounds of Perseverance's descent through the Martian atmosphere, what a working rover sounds like on Mars and even the sound of the rocks and soils when we analyse them with our SuperCam laser."

Producing oxygen

Dr Ken Williford

"We have an instrument called MOXIE that takes in carbon dioxide from the Martian atmosphere and converts it to oxygen. This is a small-scale demonstration of a technology that could one day be scaled up to provide oxygen for astronauts to breathe or as rocket propellant to help return them to Earth."



New landing sensor

Dr Kathryn Stack Morgan

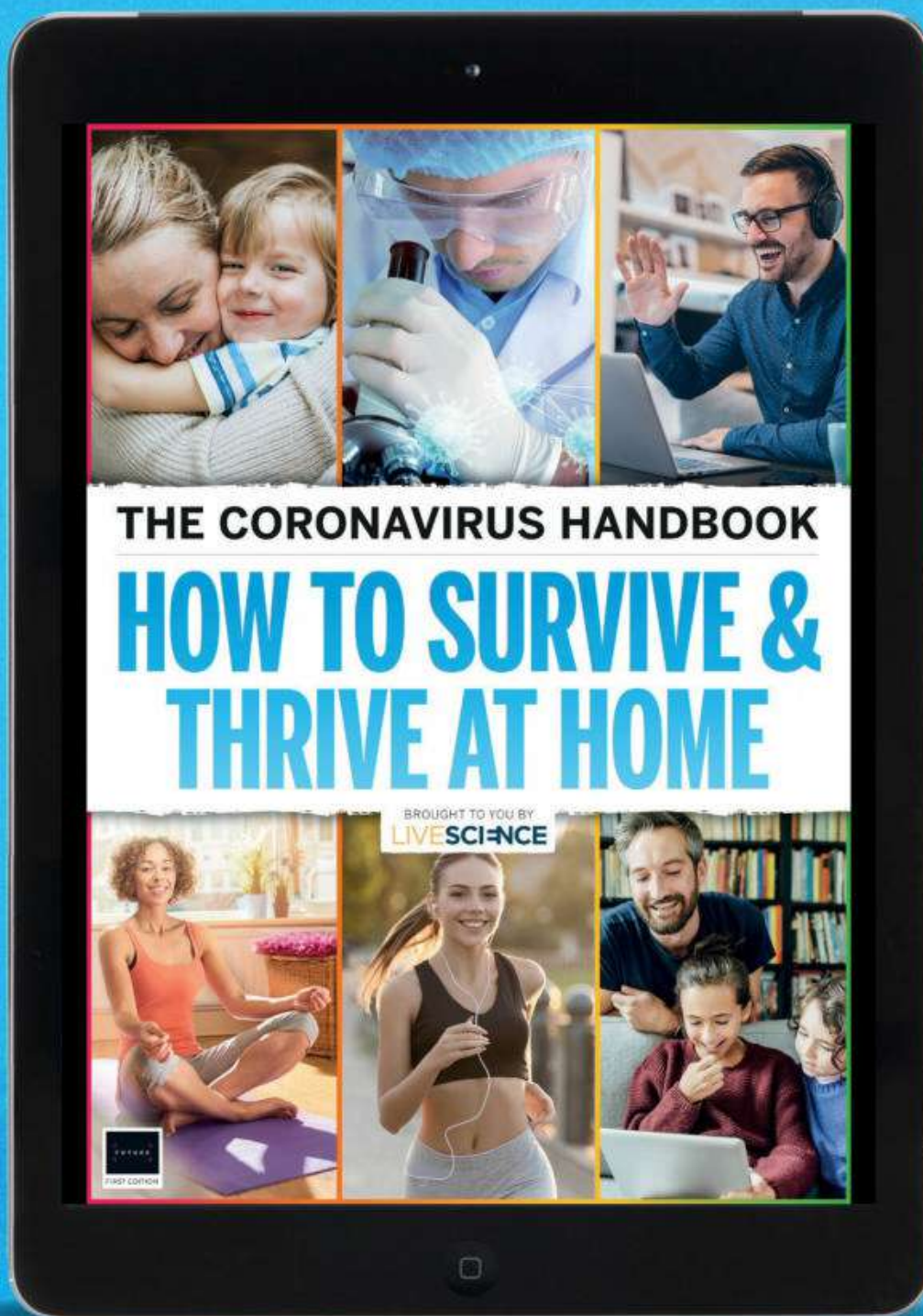
"Although many aspects of the Mars 2020 landing system are heritage from the MSL mission, we will use a new capability called Terrain Relative Navigation (TRN) along with the rover's enhanced computer processor to avoid terrain hazards as we're approaching our landing site in Jezero crater. Previous missions deemed Jezero crater too unsafe to land, so it's thanks to TRN that we're heading to Jezero."

FREE DIGITAL BOOK FOR YOU

THE CORONAVIRUS

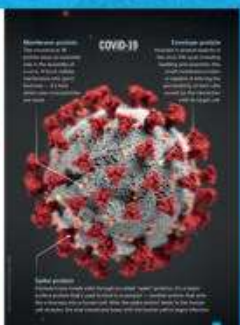
HANDBOOK

How to Survive & Thrive at Home



- What are the symptoms of coronavirus?
- How can I stop it from spreading?
- How can I protect my family?
- What is the best way of homeschooling my children?
- How can I work effectively from home?
- What's the best way of staying fit and healthy, physically and mentally?

In this handbook you'll find the answers to all these questions and more as **Live Science** keeps you up to date on the latest information on the pandemic. Providing practical advice on everything from creating an office space and finding a healthy balance between parenting and worklife to choosing the right diet and pastimes for you and your family, **Live Science** ensures you thrive and survive at home during these challenging times.



DOWNLOAD YOUR **FREE** COPY NOW:

howitworksdaily.com/free-ebook-the-coronavirus-handbook/

INTERVIEW BIO

Peter Beck

Peter Beck founded Rocket Lab in 2006 and still operates as CEO. He grew up in the city of Invercargill, New Zealand, developing a passion for rocketry. This passion led to the creation of his company and its influential Electron rocket, with Peter at the helm as the company's head visionary and chief engineer.

He has been given many awards back in his home country of New Zealand, receiving the Cooper Medal, presented by New Zealand's Royal Society, New Zealander of the Year and New Zealand EY Entrepreneur of the Year. He has also received the Meritorious Medal from the Royal Aeronautical Society.

THE MAN BEHIND ROCKET LAB

All About Space speaks to the CEO and founder of Rocket Lab about the company's successes in 2019, what the future holds in its collaboration with NASA and how SpaceX's Starlink could impact astronomy

Interviewed by Lee Cavendish

Rocket Lab had a very successful 2019, with six successful launches, and you managed to build your American base. How do you look back on that year personally?

2019 was a solid year. 2020, at least pre-COVID, was going to be a much bigger year. I'm super proud of the team last year. Like you say, we got six vehicles away, which put us in place for being the fourth most launched rocket in the world [that year]. This year we were planning to double that, and we'll see if we can still hold to that plan.

We've got the first flight of our Photon satellite platform. We acquired a satellite company with similar components and we've moved much further down the road for recovery as well. So 2020, even though it's early days, is shaping up to be a really big year, but I'm super proud of the team for 2019.

To come along so quickly in just a year is a massive achievement. What do you put that down to?

Relentless execution by a very dedicated team. That's all it comes down to. I think Rocket Lab's approach is really good. We try to strike the balance between spending time in analysis and spending time on testing. It is striking that balance - if you spend too much time on one side, like analysis, it will take years and years and years to build anything. If you spend too much on the other side, in testing, and you just keep blowing stuff up, you don't move forward. It's finding that middle ground where there's an optimum point and you get the maximum development.

Since Rocket Lab's inception, can you pinpoint a make-or-break moment for the company? Or, being in the business of rocketry, is every launch a make-or-break moment?

The way I often describe it to people is: building a rocket company is like running in a maze in the

dark, but instead of just hitting a dead end, there's a guy there standing with a shotgun.

You've got to run through this maze and make all the right decisions. But you also have to be cautious enough to just poke your head around the corner, and if you see the guy standing there with a shotgun, you have to have the courage to stop what you're doing and change direction, but not always stopping and changing your direction too early, otherwise you never get through the maze.

Before COVID-19 hit, Rocket Lab had some success testing how to catch a rocket stage in midair using helicopters. Can you tell us more about that?

The plan here for the reuse and recovery of stage one [of the Electron rocket] is a little bit different to the proven techniques. With a small launch vehicle you don't have the propellant reserves to do

propulsive landings. If you did you turn a small launch vehicle into a large launch vehicle and that defeats the purpose.

The plan for us here is as we descend through the atmosphere, the stage is guided through a very, very narrow corridor - and we've proven

we can do that now twice in a row and keep the stage healthy and in one piece - then we deploy some decelerators, some parachutes, and get it 'under chute'. Then once it's 'under chute' we want to snag it before it lands in the ocean, because that is not good for a rocket, that's for sure. Especially one like ours, which is heavily software and electronics based.

There are three big pillars that we need to do [to capture and reuse a rocket]. The first one is reentering, which we've proven. The second one is parachuting; Flight 17 has a block upgrade which we will try to put parachutes on. And then the third thing that we need to try and prove is can



Above: Beck hopes Rocket Lab can collect its main stages by intercepting and catching them with a helicopter in the near future

Right: Rocket Lab's first commercial satellite launch occurred on 19 April 2018



Interview Peter Beck



we snatch something out of the sky as it is falling, which was the test we did recently.

Rocket Lab certainly has interesting names for its missions, such as 'That's a Funny Looking Cactus' and 'Make it Rain'. Who is coming up with these names?

Some are me, but it's also the staff. It's such a serious, high-stress business, it's nice to have something that's just a little bit comical. The first rocket was called 'It's a Test', and we had to submit a name to Space Command, and this name was going to be on the screen as it flew. As with any first vehicle, you have to be realistic in that there are so many things you can't test until you fly. I went to the team and said: "When there's something bleeping on someone's radar screen, and it's not going in the right direction, it'll be far more useful for us to just call it what it is, which is 'it's a test'."

Instead of 'RC-1130I' or something like that, it was just 'It's a Test'. When we flew the next one, it was 'Still Testing'. It wasn't intended to be funny at the start. It was intended to explain what we were doing, and after the first one we all had a laugh, so from then onwards we kept the naming regime. Every time we get a new mission, we canvas the

staff and hundreds of names come up, so we've got a good repertoire now of names for launches.

You've spoken briefly about the Photon rocket line you have coming up. Can you please expand on that?

Photon is a satellite platform, and the reason why we call it 'Photon' is that under quantum mechanics, electrons emit photons, and they're smaller than an electron. It's a satellite, and one of the things that previously frustrated me is that as I'm carrying someone's satellite to orbit, beneath it I have everything that constitutes a satellite also. Why not just cut out the middleman and provide a satellite all ready for our customers to just integrate their sensors on?

We look at the launch and we see launches as a solved problem. But we look at satellites and we think there's a lot of work to go there. Throughout my career I've seen so many start-up companies go and raise a bunch of money, build a team, they go and build their first satellite and they put it on orbit and it fails. It doesn't fail because their sensor doesn't work. It fails because of something stupid like a reaction wheel, a star tracker or something to do with the base infrastructure of the satellite.

Right: Rocket Lab's Photon satellite bus aims to assist governments and companies in launching sensors and equipment

Below: Rocket Lab launched an impressive six rockets in 2019 and strives to continue this success



What we're trying to do is provide a base platform where satellite companies and governments only need to worry about the thing that generates some revenue, or generates some capability, and that is the sensor.

Soon there will be a NASA mission being launched via Rocket Lab as well. Could you tell us a bit about that?

This mission is one that we have sort of flown once already for NASA, whereas the next launch vehicle that's currently sitting on the pad has a NASA payload as well. But the CAPSTONE [Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment] mission is just an awesome mission.

That mission really leverages our Photon satellite platform to the maximum. It is the most potent version of it possible. What that enables us to do is get 35 kilograms (77 pounds) to the Moon. The CAPSTONE mission is the first spacecraft to go into the [lunar] gateway to start building infrastructure so that the gateway will allow humans to return to the Moon.

It's an incredibly wonderful mission and an honour to be involved in it. But what it does now is, with the creation of Photon, we can provide satellites for our customers all the way up to the Moon or even interplanetary. We can get 25 kilograms (55 pounds) to Venus and the same to Mars. We've built a real capability there now.

I guess the most exciting thing for me about that whole capability is not just the engineering feat - which it really is with the trajectory in the GNC [Guidance, Navigation and Control] trickery - it's the fact that you can now go to the Moon, or to Mars or Venus, for under \$20 million [£16.2 million]. Historically you wouldn't even get a study for that, and now you can actually do it. I'm super excited about what that means for planetary science, and what missions we can do now for such ridiculously low prices.

Are space and planetary science aspects that you're interested in, or is it mainly rocketry?

Rocket Lab is definitely a space company now, so we're known for our Electron launch vehicle. But we also have our Photon satellite line. We've also purchased a company that produces satellite components. We actually manage satellites for governments, so we're very much a space company across all of those centres.

But I guess for me personally, I have a deep passion for Venus. I think Venus is a very, very underrated planet. Mars - everyone's excited about Mars. I couldn't care less about Mars at all. I'm very excited about Venus.

I'm excited about Venus because Venus is like Earth if climate change goes wrong. And I think there's a lot to be learned from Venus. Also, the closest probable candidate to prove life exists

Right: Beck is particularly excited about the launch of NASA's CAPSTONE mission, which contributes to the dawn of a lunar gateway



"I'M EXCITED ABOUT VENUS BECAUSE ITS LIKE EARTH IF CLIMATE CHANGE GOES WRONG. AND I THINK THERE'S A LOT TO BE LEARNED"

outside of Earth is still Venus. I think within Venus' atmosphere there's an area - a regime - in the air which is moderate. But you know, the jury's still out on whether or not there could be bacteria living in Venus' atmosphere.

That's what gets me excited about Venus. Nobody will even step foot on Venus. That's one thing that Mars has got going for it. But as a planet, and as something to learn from, I think [Venus has got] a lot more going for it.

As someone who launches satellites, you must think it's almost criminal how only a few satellites have actually been launched to survey Venus, especially compared to Mars?

Yeah. Absolutely. I mean, the longest a spacecraft has survived on Venus is 52 minutes. It's 90 atmospheres on the surface and hot enough to melt lead, so it's incredibly difficult to get to the surface. Mars is a piece of cake. There's just a thick enough atmosphere and you can get to the ground and it's fine. Venus, however, is a very challenging environment for exploration.

SpaceX has recently come under some criticism from the astronomy community due to its Starlink satellite constellations. What are your thoughts on how your business might similarly affect night-sky observers and on SpaceX's Starlink situation?

I've been hammered on this one. If you go back to January 2018 I launched the Humanity Star, which was a twinkling 'star' in the sky. The purpose of that was for everybody to look up and appreciate the planet that they're on and the vastness of the

universe. It lived for three months. I put it in an orbit that was decaying very quickly.

That was a very painful time. A lot of people really didn't like that. A lot of people really did. In fact, probably more people liked it than didn't like it. But the people who didn't like it got a very strong, solid platform. It obviously taught me a lot, but I think it raised awareness, which was great.

However, if you're going to try and put up [over] 30,000 satellites, that becomes a real problem. And I know that there's a lot of talks right now about what it means for Earth observation of our universe, but we have to deal with this as well as a launch vehicle provider.

When the Starlink satellites were first launched, they were in the 'string of pearls'. And we've had two launches now where we've tried to launch and those 'string of pearls' have coincided with our launch. We end up with a bunch of one-minute launch windows because we have to shoot the rocket in between satellites as they go over, so if you've got 30,000, that becomes infinitely more difficult to launch. And it's not just Starlink - there's a number of these constellations being planned. There's the Amazon constellation and a number of others too.

There needs to be more global management of how we're going to deal with these large numbers of spacecraft in orbit, because at the moment there is no real framework in place. [At the moment, for example,] somebody in Europe sends somebody in the US an email saying: "Hey, you need to move your satellite because it's getting a bit close," and that logs into a terminal and moves the satellite. This needs to be autonomous.

**HOW IT
WORKS**

SPECIAL
subscription offer

SUBSCRIBE TODAY AND RECEIVE 3 FREE POCKET MANUALS*



Deadly Creatures

This book is filled with information, facts and figures on some of the most dangerous predators in the animal kingdom, from fearsome big cats and bears to small but toxic scorpions and spiders.



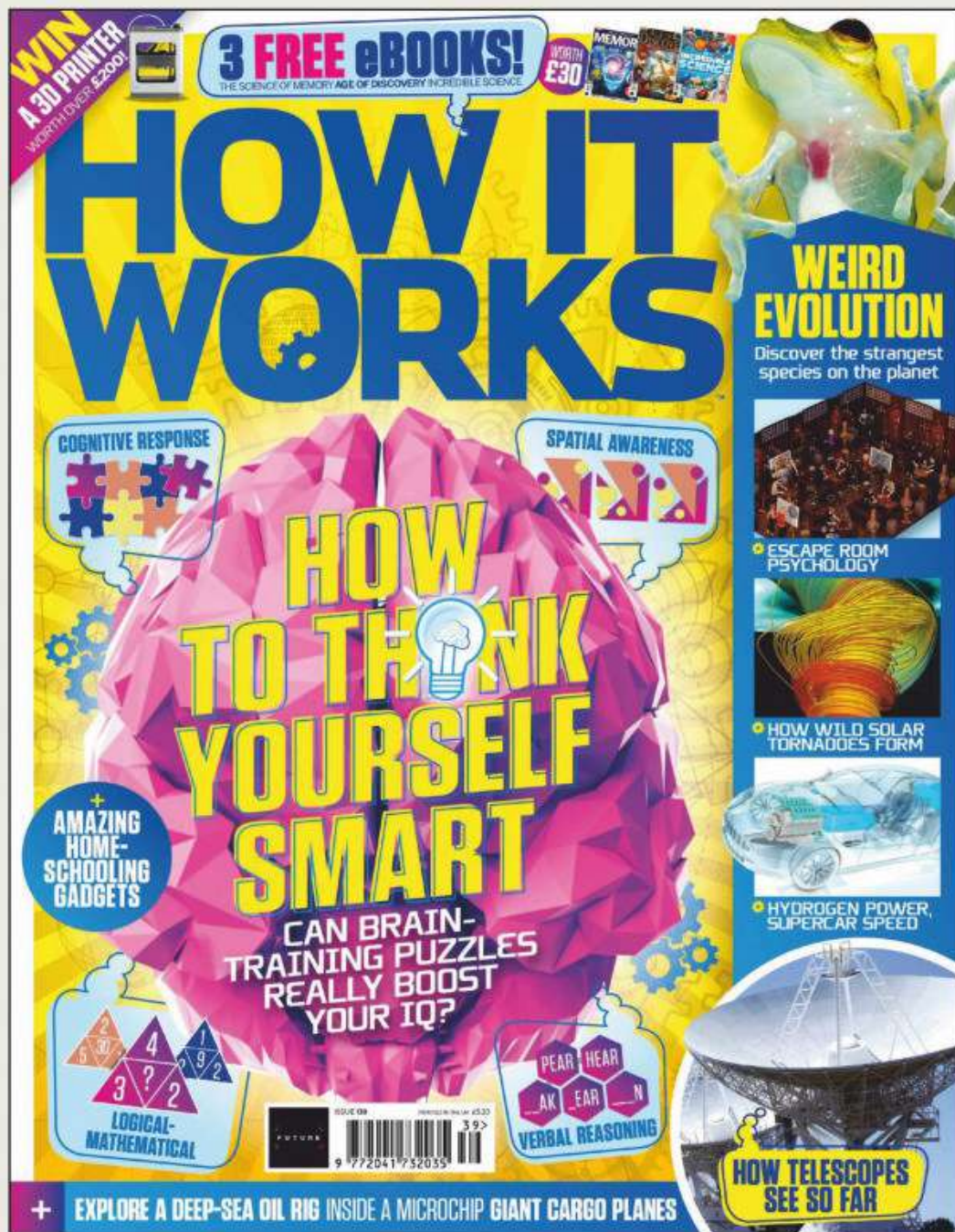
Dinosaurs

45 species of dinosaur, from favourites such as the Stegosaurus and Triceratops to the unusual Therizinosaurus – and of course the notorious Tyrannosaurus rex – are all covered in this pocket manual.



Extreme Cars

Fast-and-furious facts for each entry include highest speeds, engine capacity, power-to-weight ratios, dimensions and fuel consumption, all accompanied by awe-inspiring photos of these extreme autos.



WHY SUBSCRIBE?

- Brilliant value – save money on the cover price
- You'll never miss an issue
- Delivery direct to you



Subscribe now

www.myfavouritemagazines.co.uk/hiw/hiw139a



£20.50
SAVING 36%

PRINT

Six-month subscription to **How It Works** in print plus three pocket manuals



£14.25
SAVING 45%

DIGITAL

Six-month subscription to **How It Works** in digital



*Terms and conditions: This offer entitles new UK Direct Debit subscribers to pay just £20.50 every six months plus receive three pocket manuals. Gift is only available for new UK print subscribers. Gift is subject to availability. Please allow up to 60 days for the delivery of your gift. In the event of stocks being exhausted we reserve the right to replace with items of similar value. Prices and savings quoted are compared to buying full-priced print issues (£5.20) and full-price digital issues (£3.99). You will receive 13 issues in a year. Your subscription is for the minimum term specified. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. UK calls will cost the same as other standard fixed-line numbers (starting 01 or 02) or are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: bit.ly/magterms. Offer ends 4 July 2020

WHAT WOULD YOU SOUND LIKE ON OTHER WORLDS?



ALL ABOUT SPACE REVEALS HOW THE HUMAN VOICE WOULD DIFFER IF ASTRONAUTS WERE ABLE TO TALK ON OTHER WORLDS

Written by Lee Cavendish

Testing your vocal cords on another planet is a deadly experiment. If you were to voyage to another planet, step out of your spaceship and remove your helmet in order to announce your arrival, you'd be dead within minutes... or even seconds. However, if you were able to speak on other planets and moons throughout the Solar System, the varied atmospheres and surface conditions would affect your vocal cords in a different way than on Earth, making you sound like a different person.

Your ability to speak is possible because of airflow vibrating against the larynx, producing sound waves that then propagate through the atmosphere, which are then carried to, and received by, the eardrums. But what happens if the atmosphere, the medium for voice vibrations, and the surface conditions are tweaked somewhat?

Why aren't there more worlds?

Although this is a hypothetical scenario, these are the only worlds with a rocky surface and dense enough atmosphere to be considered for this exercise. Mercury does not have an atmosphere and Jupiter, Saturn, Uranus and Neptune are all essentially just big balls of gas with no substantial surface.



Many aspects of the human voice are determined by the atmosphere at surface level on Earth

EARTH

On Earth we are currently in a settled state of verbal communication. Earth sits in the Goldilocks Zone of habitability, where the planet is not too far away from the Sun. It's here where the temperature is just right, where the atmosphere evolved in such a way that made our planet an ideal spot for life to thrive.

As an evolutionary consequence, our voices have adapted to this friendly atmosphere that consists mostly of nitrogen. These atoms are relatively heavy and make up roughly 78 per cent of the atmosphere. Oxygen is the second most abundant, comprising 20 per cent, and the rest is made up of small amounts of argon, carbon dioxide and other gases.

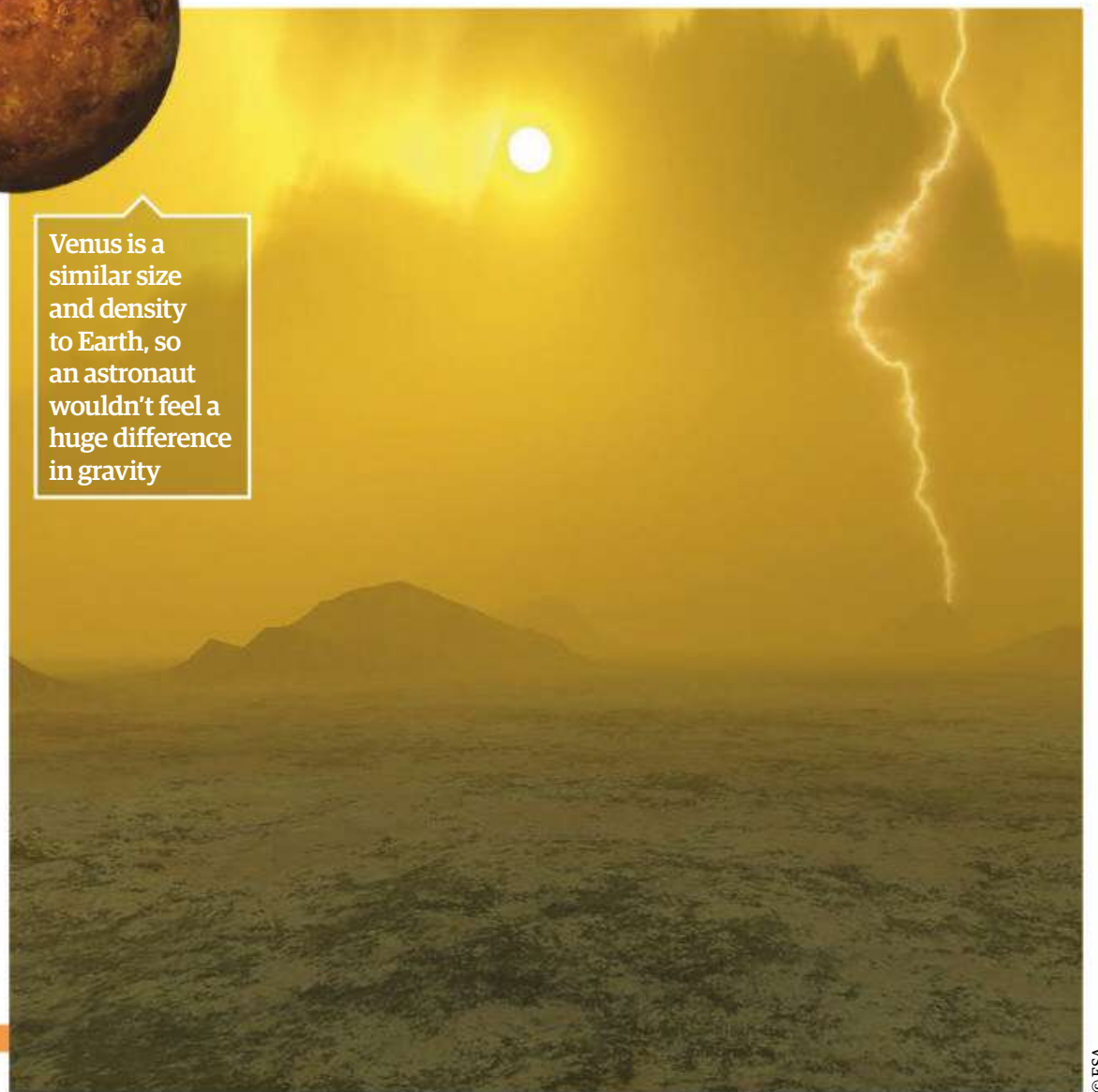
Carbon dioxide is much more prevalent in the atmospheres of our neighbouring planets, and this alone makes a huge change to the way our voices would sound. With it only in a small abundance on Earth it does not absorb as many vibrations, thus allowing screams and shouts to carry much farther.

VENUS

If this thought experiment became a reality, an astronaut would have to endure landing on a surface with pressures similar to swimming 900 metres (3,000 feet) below Earth's surface level. Not only that but Venus has the most intense temperatures of any planet in the Solar System. The average temperature is about 465 degrees Celsius (869 degrees Fahrenheit), which is hot enough to melt lead. The atmosphere of Venus is almost entirely carbon dioxide, with the percentage being a substantial 96 per cent.

The higher density of the air would cause your vocal cords to vibrate slower, meaning the pitch would be lower by half an octave. Simultaneously, the thick smog would cause the sound to travel faster, as the atmosphere acts more like a liquid than a gas. This would cause the frequency to be higher, so sounds would be squeakier as a consequence. Along with the fact that the predominantly carbon-dioxide atmosphere would absorb the waves, stifling them, your voice on Venus would sound as if you're doing a Donald Duck impression from far away.

Venus is a similar size and density to Earth, so an astronaut wouldn't feel a huge difference in gravity



© ESA

Similarities between Venus, Earth and Mars

The second, third and fourth planets from the Sun have many similarities. They all have iron-nickel cores with rocky crusts, and with this base they were able to accrete an atmosphere.

Although they exhibit different surface conditions along the spectrum from hot to cold, it could be that at one point over the last 4.6 billion years they could all have had surface water and possibly microbial life.

MARS

After being stripped away over billions of years, Mars has a very thin atmosphere. Similarly to Venus, it is almost entirely made up of carbon dioxide, with a similar percentage. However, unlike "Earth's evil twin", the atmosphere of Mars has a surface pressure equivalent to one per cent of Earth's at sea level and experiences an average freezing temperature of minus 63 degrees Celsius (minus 81 degrees Fahrenheit).

The carbon dioxide would once again absorb the vibrations, making your voice sound quieter. In fact, a speaker blaring out your favourite song would be barely audible if placed nine metres (30 feet) away. The other major difference on Mars is that the cold would lower the pitch of your voice, adding a huskier tone to it.

The Red Planet has the thinnest atmosphere of all the bodies here, so it would be difficult to send sound waves very far





TITAN

It's not a planet, but Saturn's moon Titan is arguably the most similar world to Earth in the Solar System. It is the only moon in our cosmic backyard to have a dense atmosphere, which is 95 per cent nitrogen, and even experiences a rain cycle similar to Earth's.

At the surface the air pressure is comparable to someone swimming roughly 15 metres (50 feet) deep in the ocean on Earth, combined with the moon's chilly temperatures. As Titan is nine-times farther away from the Sun than Earth, it receives a fraction of the sunlight, experiencing an average surface temperature of minus 179 degrees Celsius (minus 290 degrees Fahrenheit).

The similarity in atmospheric composition between Titan and Earth will give a recognisable tone to your voice, but with two main differences. The higher air pressure will cause the vibrations to travel slower and give slightly more bass to your voice. Secondly, as Titan's atmosphere is more abundant in nitrogen, the sound waves would be carried further, meaning that your voice would also appear louder to the receiver. This means that you could call out to a fellow astronaut at a great distance to tell them you're about to take a dip in the ocean of liquid methane.

Artists' impressions of Titan paint a picture of a gloomy world. Titan's atmosphere presents a thick orange haze that makes the moon difficult to observe

The tantalising prospect of Titan

Titan may be seen by some as 'just another moon' - after all, Saturn alone has over 80 of them - however, there is much more complexity to it. This world has a dense atmosphere, and underneath it are oceans of liquid hydrocarbons. NASA's Cassini spacecraft even observed a rain cycle occurring on Titan during its flybys. This is why many space agencies are planning future investigations of this distant moon, including NASA's proposed Dragonfly quadcopter.

NANCY GRACE ROMAN SPACE TELESCOPE

Dr Roman was NASA's first chief of astronomy and revolutionised how the cosmos is probed

Reported by Lee Cavendish

NASA takes pride in naming its telescopes after influential figures from the history of astronomy. Two major examples being the Hubble Space Telescope, named after famous American astronomer Edwin Hubble, and the James Webb Space Telescope, in recognition of the second NASA administrator who oversaw the agency during a monumental era for spaceflight from 1961 to 1968.

Following this theme, NASA has recently announced that it will be renaming what was previously known as the Wide Field Infrared Survey Telescope (WFIRST) to the Nancy Grace Roman Space Telescope. This remarkable woman was NASA's first chief of astronomy after arriving at the space agency in 1959 and pioneered the use of space telescopes for broader universal observations. Without her there would likely be no Hubble or James Webb and Roman established a well-respected legacy in the astronomical community before her passing in 2018.

"It is because of Nancy Grace Roman's leadership and vision that NASA became a pioneer in astrophysics and launched Hubble, the world's most powerful and productive space telescope," said NASA administrator Jim Bridenstine. "I can think of no better name for WFIRST, which will be the successor to NASA's Hubble and Webb Telescopes."

An incredibly moving tribute was also given by former senator Barbara Mikulski, who worked with NASA on the Hubble and WFIRST space

telescopes: "It is fitting that as we celebrate the 100th anniversary of women's suffrage, NASA has announced the name of its new WFIRST telescope in honour of Dr Nancy Roman, the 'Mother of Hubble' - well deserved. It recognises the incredible achievements of women in science and moves us even closer to no more hidden figures and no more hidden galaxies."

The Nancy Grace Roman Space Telescope - Roman for short - will flaunt a 2.4-metre (7.9-foot) diameter primary mirror and is due to launch in 2025. It has a variety of objectives ranging from searching for exoplanets to understanding the elusive dark energy. Infrared is perfect for this purpose as it focuses on a particular wavelength of light that is invisible to the human eye. Another unique benefit of infrared astronomy is that it allows astronomers to look at light from distant regions of the cosmos due to a phenomenon known as 'cosmological redshifting', which is when light is stretched from distant sources as it travels through space, making it shift towards the red end of the light spectrum.

Compared to Hubble, which can only see in the visible and ultraviolet wavelengths of light, it has a field of view 100-times greater. This means that it can gather more data from different sources while staring at the same patch of sky. With this exhilarating array of capabilities, it seems only fitting to name the telescope after a woman who made great developments in astronomy.

Below: A rendered model of the future telescope, planned for a 2025 launch

"IT IS BECAUSE OF NANCY GRACE ROMAN'S LEADERSHIP AND VISION THAT NASA BECAME A PIONEER IN ASTROPHYSICS"

SIZZLING SUMMER NEBULAE

Take a tour of some of the treasures held
in the warm Northern Hemisphere

Summer: where the days are longer and the nights are shorter and lighter. Many look forward to the warmer weather as spring makes way for the extra hours of daylight. But more often than not the astronomer has turned their attention to the most obvious target in the sky – the Sun. Many find that unless you're willing to stay up late and wait for our star's very last rays to leave the sky and plummet the hemisphere into darkness, night-sky astronomy needs to take a back seat until the cooler and longer nights draw back in.

It's true that summer is a tricky time of year to get the darkest of skies, but that's not to say that observing its treasures is impossible. Both star-birth nebulae and planetary nebulae – which astronomers like to call faint fuzzies – are well worth pulling out your telescope or scanning the skies with your binoculars for. If you're out of the way of light pollution and have given your eyes at least 20 minutes to adjust to the darkness, the better the views will be.

As we've already hinted, there are several types of nebulae. Planetary nebulae, dark nebulae and diffuse nebulae are the main ones you'll find in the night sky. However, to figure out the type you're looking at requires a bit of practice and ample equipment to capture these targets at their very best.

As with any night-sky observing, the larger the aperture of your telescope or binoculars, the more light your instrument will be able to collect. This will make it far easier to see your chosen target in all its glory.



Nebulae-hunter's note

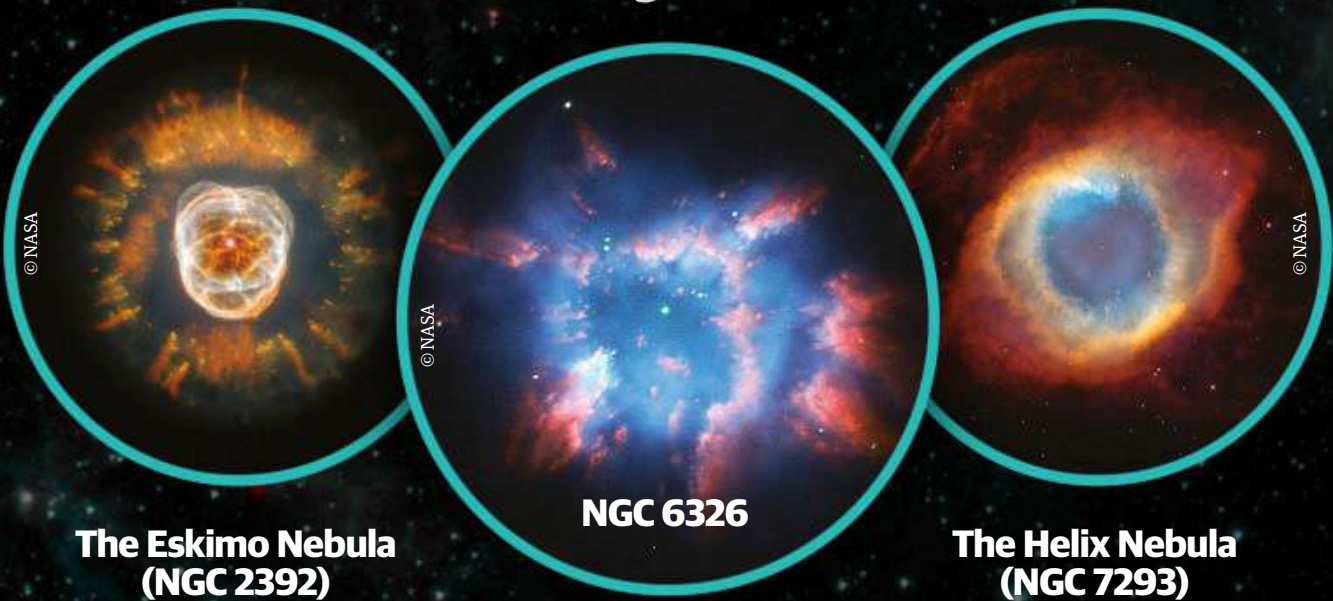
In images taken by the likes of the Hubble Space Telescope, nebulae appear large and beautifully coloured. Remember, the size and power of professional telescopes does not compare with your back-garden 'scope. This means that the nebulae you'll see will be grey in colour and much, much smaller. Luckily, with filters such as OIII and UHC, as well as some astrophotography techniques, you can add that much-needed splash of colour!

© Adrian Mann

Meet the family of nebulae

From the messy to the beautifully defined, there are many different nebulae to feast your eyes on

Planetary nebulae



Diffuse nebulae

Emission nebulae



The Flame Nebula (NGC 2024)



IC 2944



The Monkey Head Nebula (NGC 2174)



The Carina Nebula (NGC 3372)



NGC 6357



The Bubble Nebula (NGC 7635)



The Snake Nebula (Barnard 72)



The Horsehead Nebula (Barnard 33)



The Pipe Nebula (Barnard 59)



The Witch Head Nebula (NGC 1909)



Messier 78



The Ghost Nebula (vdB 141)

Reflection nebulae

NEBULAE WITH YOUR BINOCULARS

Sweep the summer skies for the best nebulae using nothing more than a pair of binoculars



© NASA, Source: Wikipedia Commons © Martin MacPhee

Eagle Nebula (M16)

Constellation: Serpens (the Serpent) **Right ascension:** 18h 18m 48s

Declination: -13° 49' **Magnitude:** +6.0

The Eagle Nebula is a bit tricky during the summer nights, but with a careful eye you can spot it. It's home to a cluster of stars that are easier to see than the nebula itself. It's also famous for being the home of the Pillars of Creation, but you'll need a 12-inch telescope or an astrophotography camera to see those.

Trifid Nebula (M20)

Constellation: Sagittarius (the Archer)

Right ascension: 18h 02m 23s

Declination: -23° 01' 48" **Magnitude:** +6.3

Near to the Lagoon Nebula is the Trifid Nebula, about two degrees - four full Moon diameters - to the north of M8. Your binoculars will show a bright but hazy nebulous object, but to see the Trifid's four petals, which are parts of this nebula separated by dust lanes, you'll need an eight-inch telescope. A small telescope of about four inches will show some of the blue reflection nebosity in the Trifid.



© ESO, Source: Wikipedia Commons © Hewholooks



Lagoon Nebula (M8)

Constellation: Sagittarius (the Archer)

Right ascension: 18h 03m 37s

Declination: -24° 23' 12"

Magnitude: +6.0

Although it appears low in the sky from northern Europe, the Lagoon Nebula is a brilliant target for observers with binoculars. You'll see a large fuzzy blob 1.5 degrees across from east to west, which is three times the size of the full Moon. A small telescope shows even more detail, including its characteristic dark dust lane that runs through the middle.



© ESO, Source: Wikipedia Commons © Miodrag Sekulic

© NASA; Source: Wikipedia Commons © Hewholooks



Wizard Nebula (NGC 7380)

Constellation: Cepheus (the King)

Right ascension: 22h 47m

Declination: +58° 06' **Magnitude:** +7.2

This nebula is really tough to spot. Try with binoculars, which are preferred for viewing the cluster of stars, but if no luck then look through a small telescope using an OIII filter with averted vision - you should then see a curved shape.

© NASA/JPL-Caltech; Source: Wikipedia Commons © Nynny



North America Nebula (NGC 7000)

Constellation: Cygnus (the Swan)

Right ascension: 20h 59m 17s

Declination: +44° 31' 44" **Magnitude:** +4.0

While its brighter area is visible to the naked eye under excellent conditions, NGC 7000 is best observed with optical aid. A pair of 7x50 binoculars will enable you to identify it with ease, provided you know where to look.

© NOAO; Source: Wikipedia Commons © Hewholooks

Iris Nebula (NGC 7023)

Constellation: Cepheus (the King)

Right ascension: 21h 01m 35.6s

Declination: 68° 10' 10"

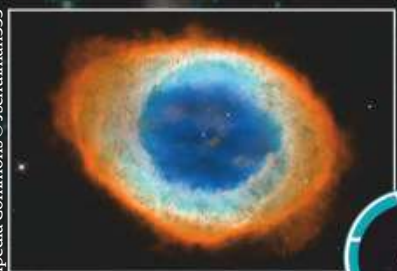
Magnitude: +6.8

This is a reflection nebula being lit up by one star. At magnitude seven this star doesn't seem too bright to us 1,400 light years away, but in reality it's 180-times more luminous than the Sun. You'll see a faint nebula, with the star appearing most notable. Though the nebula is slightly brighter than the star, its light is spread over a larger area, so it's harder to see.



TARGET NEBULAE WITH YOUR TELESCOPE

Peer deeper into the universe using greater optical aids



Ring Nebula (M57)

Constellation: Lyra (the Harp)

Right ascension: 18h 53m 35s

Declination: 33° 01' 45"

Magnitude: +8.8

Easy to find in the constellation of Lyra, a six-inch 'scope will pick out its famous hazy structure with a slight greenish tint. For eight-inch 'scopes at 100x magnification, the greenish hue becomes more prominent and a reddish outer edge appears.



Cocoon Nebula (IC 5146)

Constellation: Cygnus (the Swan)

Right ascension: 21h 53m 28.7s

Declination: 47° 16' 01"

Magnitude: +7.2

If you're under decent dark skies all you'll need is a four-inch telescope and averted vision to find this dim nebula. It's usually best viewed through an H-beta filter.



Crescent Nebula (NGC 6888)

Constellation: Cygnus (the Swan)

Right ascension: 20h 12m 7s

Declination: 38° 21.3'

Magnitude: +7.4

Made of material being ejected by a hot, massive star, the light is spread out across its large form. You will need a ten-inch telescope with the usual OIII and UHC filters to see it.



The Heart Nebula (IC 1805)

Constellation: Cassiopeia (the Queen) **Right ascension:** 02h 33m 22s

Declination: 61° 26' 36" **Magnitude:** +6.5

This area of star formation can be tricky to find at first, but it has an associated star cluster called Melotte 15 that's a good signpost. By using a low magnification in a small four- to eight-inch telescope, armed with an OIII or UHC filter, you can tease out this heart-shaped nebula from the darkness of space.



Cat's Eye Nebula (NGC 6543)

Constellation: Draco (the Dragon)

Right ascension: 17h 58m 33.4s

Declination: 66° 37' 59.5"

Magnitude: +9.8

The Cat's Eye Nebula is one of the best planetary nebulae in the sky, quite bright but small. Unlike most nebulae you can see colour in the Cat's Eye, with it looking green-blue. Use medium-powered magnification with an eight-inch telescope and you might start to pick out two lobes or rings of material ejected by the dying star in its centre.





Dumbbell Nebula (M27)
Constellation: Vulpecula (the Fox)
Right ascension: 19h 59m 36.3s
Declination: 22° 43' 16"
Magnitude: +7.5

Best viewed through OIII and UHC filters, the Dumbbell Nebula can be picked out using a small telescope. It will reveal M27 as a compact speck complete with well-defined round edges. A four-inch refractor will show the nebula's faint extensions with averted vision. A six-inch reflector under good viewing conditions at 200x to 300x power will show the central star.



© NASA/JPL-Caltech, Source: Wikipedia Commons © Oliver Stein



Pacman Nebula (NGC 281)
Constellation: Cassiopeia (the Queen)
Right ascension: 00h 52m 59.3s
Declination: 56° 37' 19"
Magnitude: +7.4

So-called as it looks a bit like the character when viewed at an angle, this is a star cluster and nebula combined. The stars stimulate the gas in the nebula, causing it to emit in H-alpha light, so an H-alpha filter will come in useful here!



Saturn Nebula (NGC 7009)
Constellation: Aquarius (the Water-Carrier)
Right ascension: 21h 04m 10.8s
Declination: -11° 21' 48.2"
Magnitude: +8.0

An OIII filter along with at least an eight-inch 'scope at 250x magnification will reveal the bright, blue-green form of NGC 7009. As one of the rare nebulae that shows colour when seen through a telescope, the nebula gets its name because of its shape, which has two protrusions that look like the planet's rings.





© NASA, Source: Wikipedia Commons © Hewholooks

© NASA, Source: Wikipedia Commons © Klaus Hohmann

The Soul Nebula (IC 1848)
Constellation: Cassiopeia (the Queen)
Right ascension: 02h 55m 24s
Declination: 60° 24' 36"
Magnitude: +6.5

Very close to the Heart Nebula is the Soul Nebula, which is a real challenge to observe visually in a four- to eight-inch telescope even with an OIII filter. If you want to get a good view of this, and perhaps see it together in all its glory with the Heart, the best option may be to image it.

63

SPACE EXPLORATION

Why are space-based Earth observations so important?

Satellites can trace the transport and transformation of atmospheric gases like ozone, carbon monoxide, nitrogen and even some organic compounds. Some of these gases can also be seen day and night. We use these gases to study how emissions from cars, industry, trees and fires all mix and change as they travel across the globe.

Studying atmospheric chemistry from the ground is like if you are trying to make a map but you can only walk over a few square kilometres and look around. If you get in a hot-air balloon, helicopter or aeroplane, you see the connections and context. It's like that for us, except with something that is evolving and changing.

Weather satellites were a huge transformation, especially for things like storms that have huge impacts

on people. Now we can see hurricanes and typhoons in advance, and all of the data from these satellites has been important in the improvement of weather forecasts.

We also have new techniques to use from space. A recent NASA article detailed the ice loss and growth on Antarctica using the space-based ICESat-2. It uses a laser to send out light pulses and then measures the timing of the returned light to get a really precise measurement of where the surface is. We are learning a lot about ice sheets and glaciers and how they evolve, which is really important for understanding our changing planet.



Dr Annmarie Eldering is deputy project scientist for NASA's Orbiting Carbon Observatory-2 (OCO-2)

Below: Satellites observing Earth have been able to reveal a lot about how our home planet is evolving

Did you know?

NASA's TIROS-1, launched in April 1960, sent back the first television footage of weather patterns to be taken from space.

EXOPLANETS

How many super-Earths are there and how will CHEOPS help to investigate them?

Short answer, lots! A key result to come from ground- and space-based planet searches is the ubiquity of small planets, with sizes and masses of up to four to ten times that of Earth. This includes so-called 'super-Earths', considered to be planets with sizes and masses of up to about 1.5 to four times that of Earth, as well as the larger mini-Neptunes. This result, together with the observed diversity in their properties and compositions, was not expected and is not well understood.

This planet population is one objective of the European Space Agency's (ESA) first dedicated exoplanet mission, CHEOPS (CHaracterising ExOPlanets Satellite). Launched in December 2019, CHEOPS is a partnership with Switzerland through a consortium led by Bern University. CHEOPS is designed to measure very precisely

and accurately the transits of known planets orbiting bright stars using the technique of ultra-high precision transit photometry.

Targeting bright host stars means that planet masses either already have been or can be measured from the ground. By combining CHEOPS' high-precision sizes with masses, we can determine the planet's bulk density with precision, enabling strong constraints to be placed on their composition and inner structure - are they rocky? Earth-like? Solid iron? Water worlds? Icy or puffy gas balls? By studying a range of different planetary systems we will progress our understanding of the formation and evolution processes of this intriguing Earth-to-Neptune-size planet population.



Dr Kate Isaak is project scientist for the European Space Agency's CHEOPS mission

ASTROPHYSICS

What do you think are the advantages of studying dark matter and dark energy in space?

With dark matter, the only way we can directly measure it at the moment is through gravitational lensing. This is when any foreground dark matter, or any foreground massive object with a large gravitational effect, distorts the shape of distant galaxies. Galaxy clusters contain 90 per cent dark matter, so they will gravitationally bend light as it travels to us from distant galaxies.

From Earth, when we measure the shapes of galaxies, we have to look at their structures through the atmosphere, clouds and things like atmospheric turbulence, so it makes it more difficult to get the shapes of these galaxies really accurate. Distortion effects typically create a one per cent change in shape.

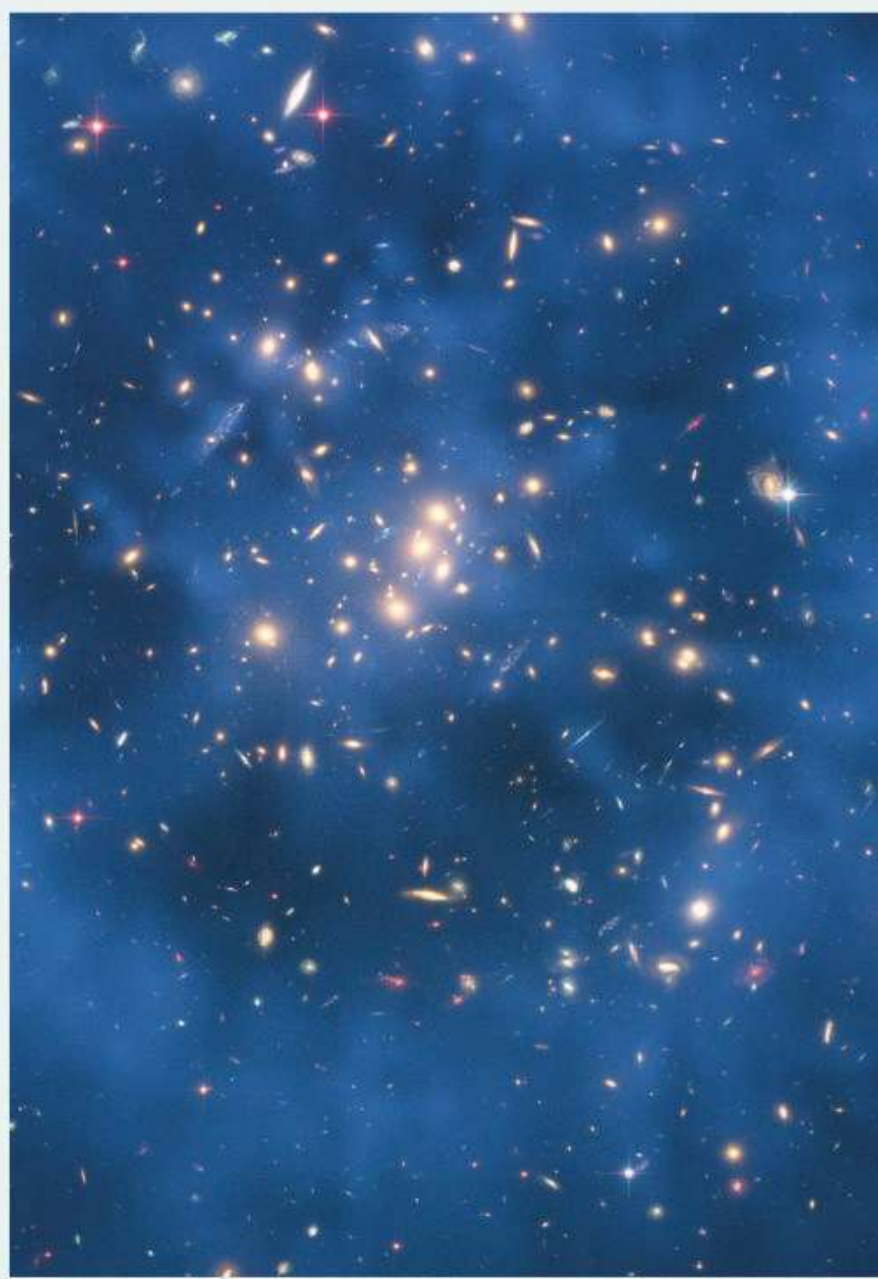
The European Space Agency's Euclid mission is a 1.2-metre (four-foot) telescope that will investigate galactic structures in space at L2 - that is one of the Lagrangian points (where the orbit is going to be super stable and so the spacecraft doesn't need to use much fuel). Euclid is an optical and infrared telescope: optical will measure the shape of galaxies very, very accurately so we can carry out gravitational lensing measurements, while infrared will see the very, very far away galaxies.



Dr Maggie Lieu is a research fellow of machine learning and cosmology at the University of Nottingham, UK

Above: Super-Earths could be another cosmic oasis for habitable life to prosper

Right: Astronomers believe they are on the verge of a huge discovery concerning dark matter



ASTROPHYSICS

How do galaxies get their shapes?

We think that galaxy shapes are forged by a combination of steady modes of growth that produce calm, ordered discs and violent events that churn galaxies into chaotic, disordered messes.

Galaxies began growing a few hundred million years after the Big Bang wherever cosmic hydrogen could condense to form stars. These nascent gas supplies continued to be replenished as gravity pulled more material in from the surrounding cosmic web.

That gas typically steadily accumulated not at the centres of galaxies but at their outskirts, because the material retained a lot of angular momentum. In this scenario, the gas settled into a thin, rotating disc. New stars then formed, staying close to the orbits of their birth clouds.

However, sometimes the gas lumps coming in from the cosmic web were massive enough to have formed their own stars prior to falling into the larger galaxy. In these cases the resultant 'merger' – accompanied by a burst of extreme star formation – is violent, throwing previously ordered stellar orbits into chaos. What remains is a jumbled collection of random orbits, taking on a spheroidal, or 'elliptical' appearance.

Dr Daniel Kelson is a researcher at the Carnegie Institution for Science, Washington, D.C.



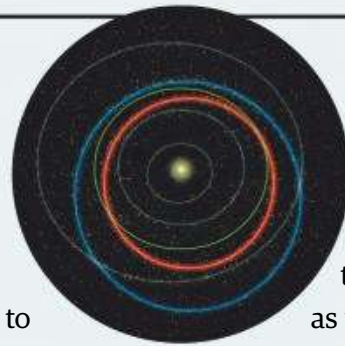
Right: Plotting the paths of asteroids is good for science and the safety of Earth

Below: Compared to Earth, Mars is roughly half the diameter and exhibits a third of its surface gravity

ASTROPHYSICS

How do astronomers determine the path of an asteroid?

The observation of an asteroid's position is defined by three numbers. The first two describe the asteroid's angular position in the sky. The third number is the time the observation is made. The distance from the observer to the asteroid is usually unknown. The problem of finding an asteroid's path from observations was first addressed by Carl Gauss in 1801 after the discovery of the first asteroid, Ceres, by Giuseppe Piazzi. They needed a year to locate the asteroid in the sky. Using Newton's law of gravitation, which stipulates that the asteroid's path is confined to a plane, Gauss showed that three observations are sufficient to determine a first approximation of the asteroid's path. Additional observations are used to refine the derived path.



Gauss' method remains the basis of current orbit determination techniques and takes into account the position of the observer on Earth, the planet's proper rotation as well as its motion around the Sun.

The method works best when the time period between the earliest and latest observations, known as the observational arc, is large.

For short arcs such as those found in single-night observations of near-Earth asteroids or those corresponding to a distant asteroid beyond Neptune's orbit, Gauss' method is complemented by statistical techniques to yield a likely orbit.



Dr Fathi Namouni is a researcher at the Université Côte d'Azur, in Nice, France

PLANETS

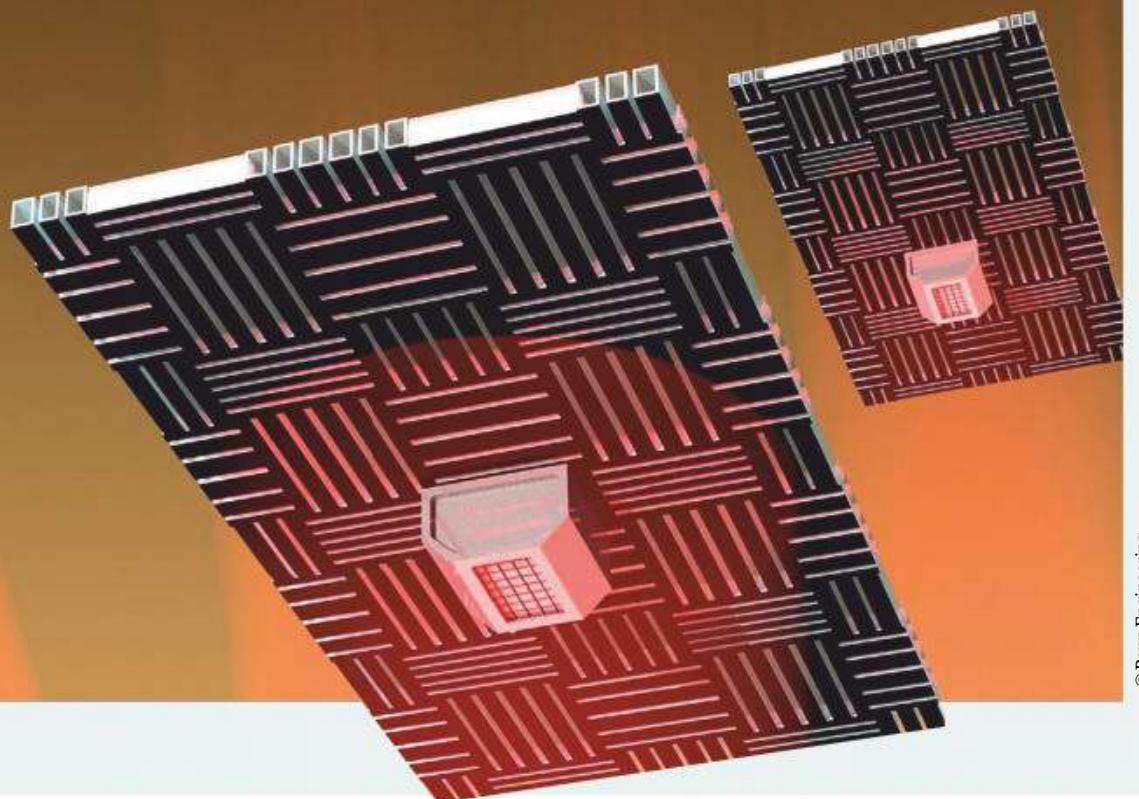
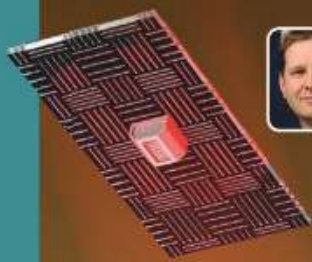
How is flying on Mars different compared to flight on Earth?

It turns out levitating is easier on Mars than on Earth. The method of levitation we developed works best for very thin air. Mars has exactly that kind of atmosphere, and in this environment it is possible to create structures that create jets of air using sunlight or a laser beam. In order to do that we use plates of nanocardboard, a lightweight material engineered specifically for this purpose. As the sunlight or laser beam is absorbed on the bottom side of the nanocardboard plate, the bottom side becomes a bit hotter than the top, and this temperature difference gets the air moving through the internal channels of the nanocardboard, creating a jet shooting air down at a speed of about one metre (3.2 feet) per second. By controlling the laser beam from the lander vehicle, we can heat some parts of the nanocardboard plate more and tilt the nanocardboard plate,



which should allow us to control the aircraft and make it go where we want.

Dr Igor Bargatin is assistant professor in the department of mechanical engineering and applied mechanics at the University of Pennsylvania, Philadelphia



Did you know?

Elon Musk has promised that the albedo, or reflectivity, of each Starlink satellite will have zero per cent impact on astronomy.

ASTRONOMY

How bad will the light pollution be when 42,000 of SpaceX's Starlink satellites are in operation?

We should not have to experience the light pollution of 42,000 Starlink satellites; it should be stopped before then. The satellites are visible with the naked eye under many circumstances, so the experience would be out of a science-fiction dystopia; skies would be crawling with hundreds of these satellites at a time like so many white maggots.

From a light-pollution perspective, the impacts of Starlink will fall into a few categories. First, the Starlink array interferes with astronomical observation and will degrade the research abilities of both professional and amateur astronomers alike. Secondly, it will degrade the experience of wilderness areas that are supposed to be protected from human interference, including impacts to aesthetics, under US law. A night-sky view with hundreds of visible satellites is fundamentally incompatible with the experience of the backcountry, outback, wilderness or the wide-open ocean. Thirdly, we

have no idea the effects that Starlink might have on wildlife that navigate by the stars or by the light of the Milky Way. It will also degrade the many cultural sites that have been built over the millennia around the human relationship with the night sky. We will never again be able to experience the sky of our ancestors, even at the most remote places on our inhabited continents.

It's not that we haven't already degraded many skies with light pollution from cities, aeroplanes and other occasional satellites, but it will be qualitatively worse to have tens of thousands of satellites, with hundreds visible through the night as they move across the sky even in locations far from the lights of settlements and commercial activity.

Dr Travis Longcore is associate adjunct professor at the Institute of the Environment and Sustainability at the University of California, Los Angeles (UCLA)



Above: SpaceX's Starlink satellites are designed to provide high-speed broadband internet access across the entire world



STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

What's in the sky?

In this issue...

68 What's in the sky?

Although the sky never truly gets dark, embrace the challenge of summer stargazing

72 Month's planets

There will be a lot going on in the sky around Venus over the next few weeks

74 Moon tour

Get views of the most striking but overlooked craters on the lunar surface: Theophilus

75 Naked eye and binocular targets

There are fascinating things to see in the night sky

76 Deep sky challenge

There's no need to put your telescope into hibernation on light summer nights

78 The Northern Hemisphere

Plenty of targets for those armed with the right kit

80 Telescope review

Is the Celestron NexStar 6SE the right telescope for you?

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light



18 JUN



Comet C/2019 U6 (Lemmon) makes its closest approach to the Sun

18 JUN



The open star cluster IC 4665 is well placed for observation in Ophiuchus

20 JUN



June solstice

25 JUN



Conjunction between Jupiter and Pluto in Sagittarius

28 JUN



Asteroid 7 Iris is well placed for observation in Sagittarius

28 JUN



Open star cluster NGC 6633 is well placed for observation in Ophiuchus

3 JUL



Asteroid 532 Herculina is well placed for observation in Sagittarius

5 JUL



Conjunction between the Moon and Jupiter in Sagittarius

8 JUL



Venus will reach its greatest brightness in the dawn sky, shining at magnitude -4.5

11 JUL



Conjunction between the Moon and Mars in Cetus

11 JUL



The Moon and Mars make a close approach, passing within 1°46' of each other in Cetus

Source: Wiki commons © Beatrice Murch





Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

21 JUN



An annular eclipse will be visible from Africa and Asia

22 JUN



Comet C/2019 U6 (Lemmon) reaches its brightest, at a predicted magnitude of +3.7

22 MAY



Open star cluster NGC 6530 is well placed for observation in Sagittarius

30 JUN



Globular cluster Messier 22 is well placed for observation in Sagittarius

1 JUL



Open star cluster IC 4756 is well placed for observation in Serpens



Source: Wiki commons
© Roberto Mura

5 JUL



The Moon and Jupiter make a close approach, passing within 1°51' of each other in Sagittarius

6 JUL



Conjunction between Saturn and the Moon in Sagittarius

6 JUL



Close approach of the Moon and Saturn in Sagittarius, passing within 2°27'

14 JUL



Jupiter reaches opposition in Sagittarius, shining at magnitude -2.7

15 JUL



Asteroid 2 Pallas reaches opposition in Sagitta, glowing at magnitude +9.6

Naked eye

Binoculars

Small telescope

Medium telescope

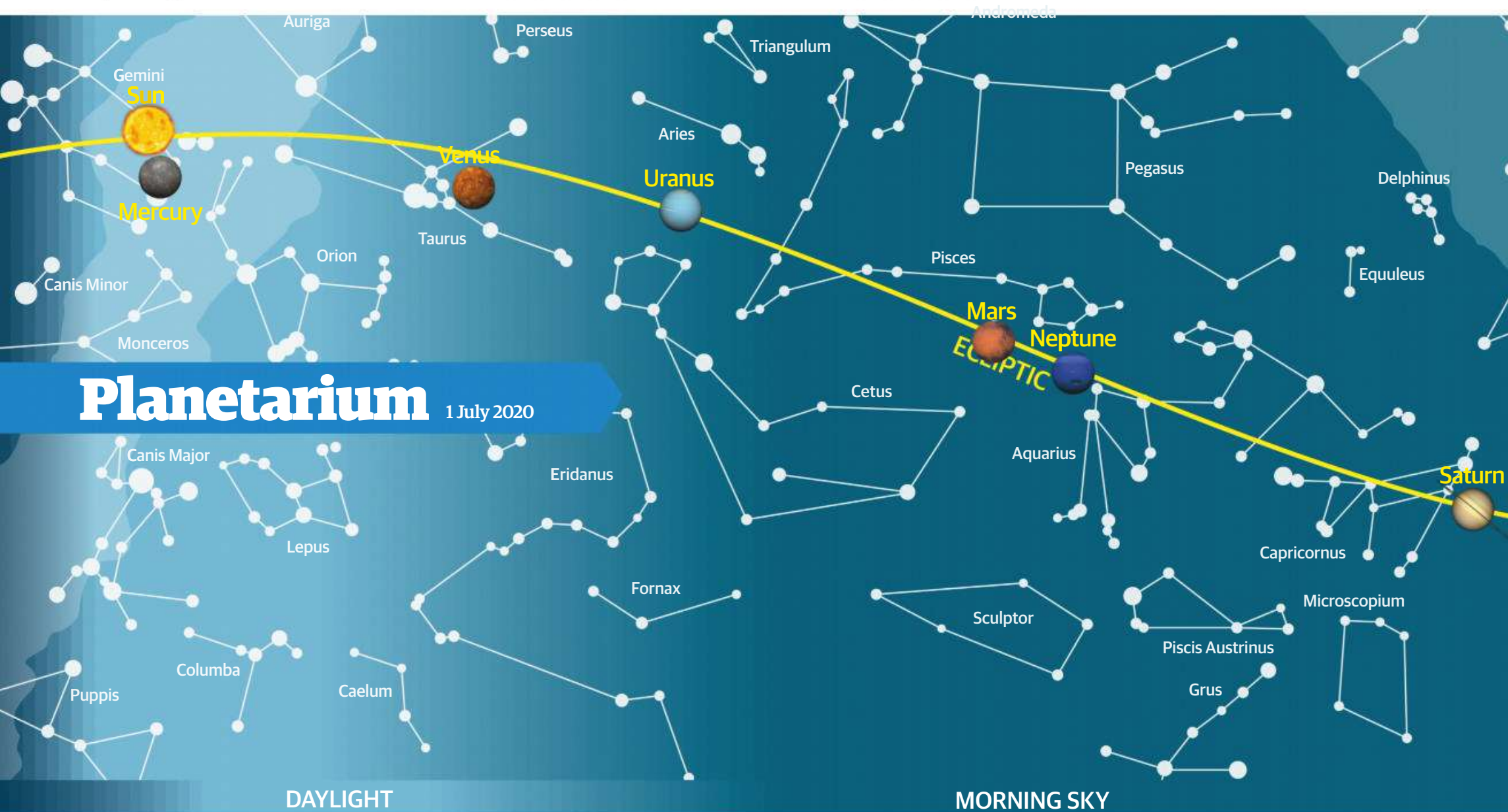
Large telescope

ASTRO QUIZZICAL
A Curious Journey Through our Cosmic Family Tree





STARGAZER



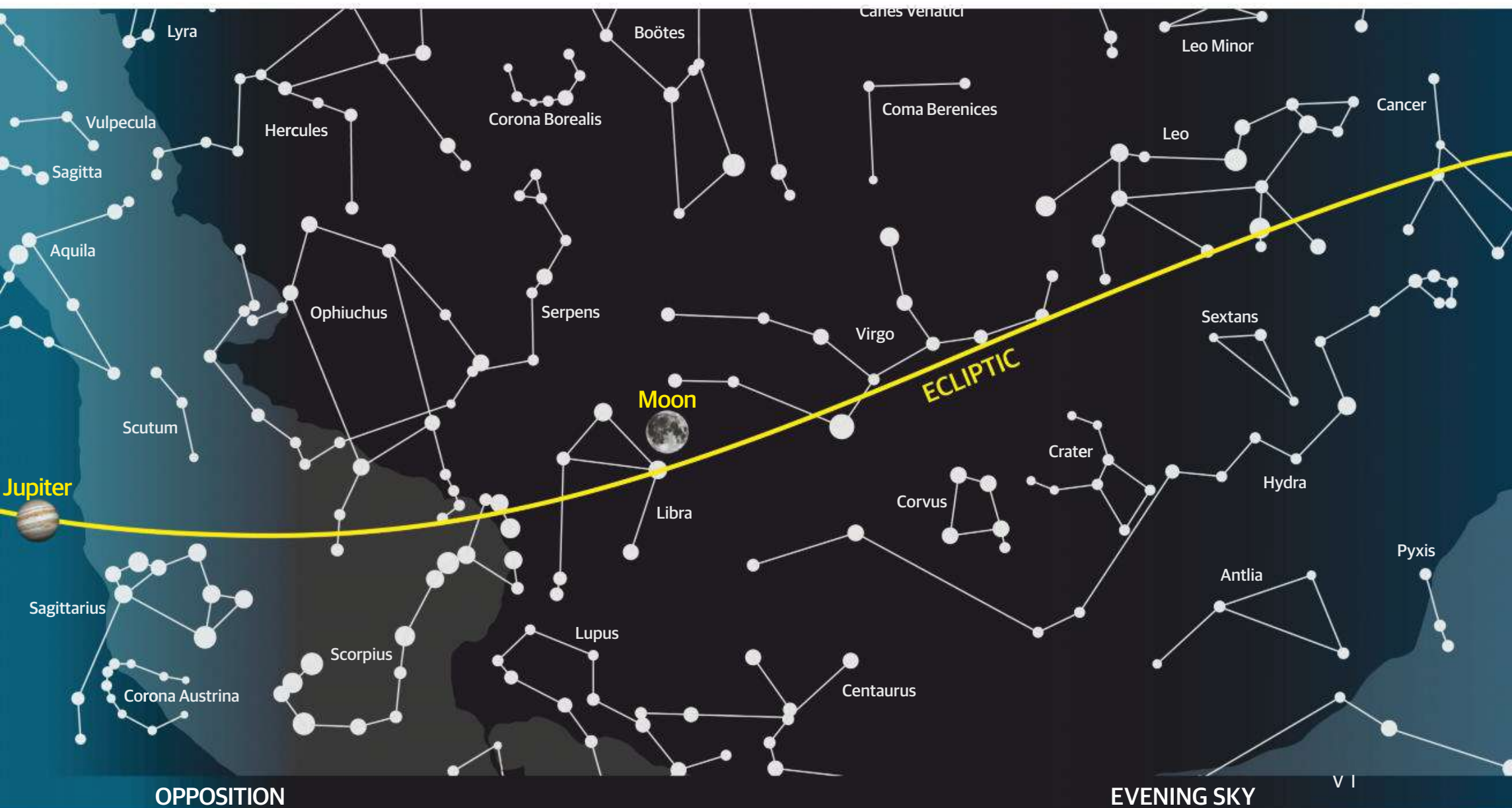
Moon calendar

* The Moon does not pass the meridian on 4 July

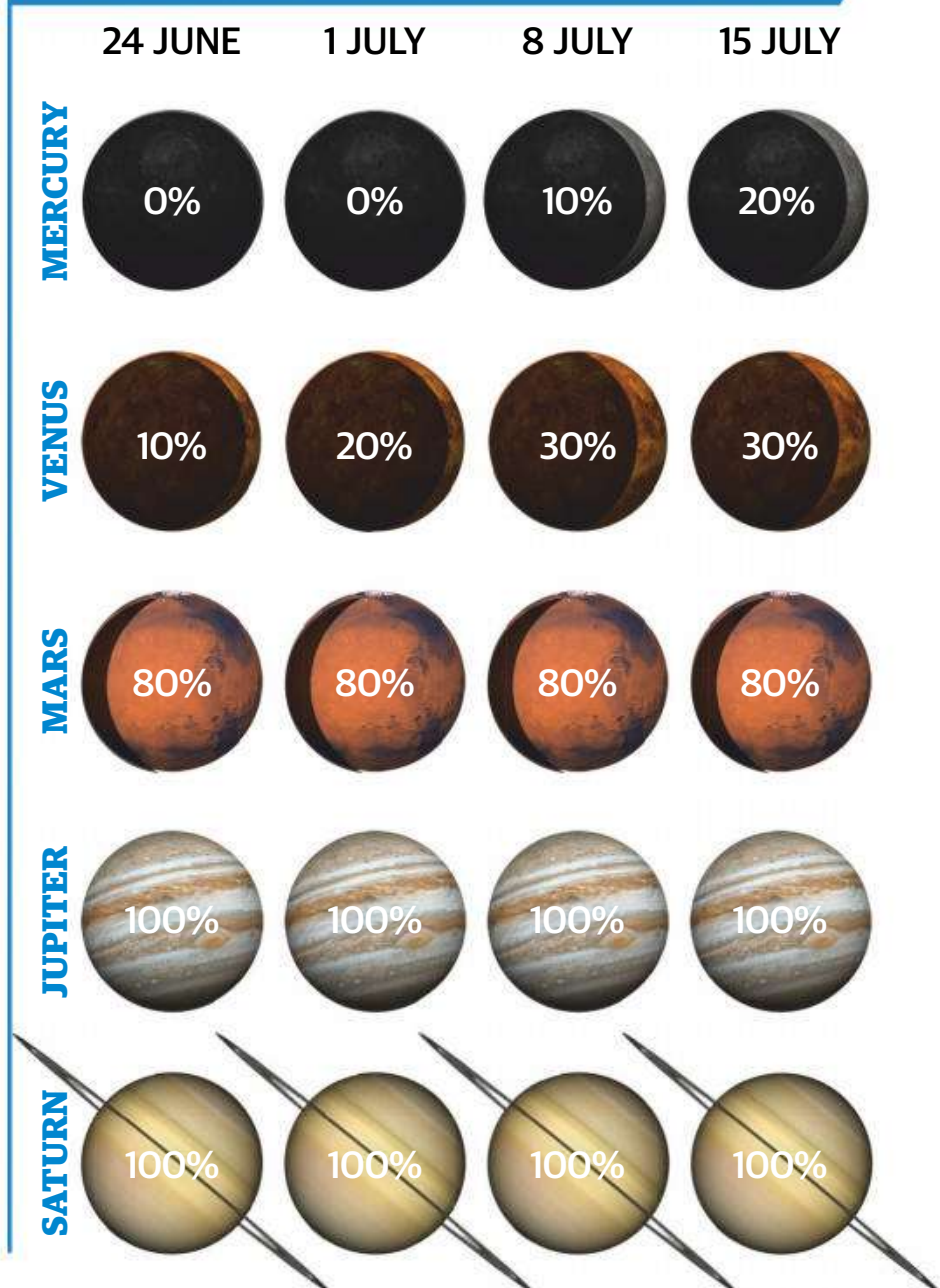
22 JUN 1.8% 05:35 22:42	23 JUN 6.1% 07:42 23:25	24 JUN 12.7% 07:49 ---	25 JUN 21.3% 00:00 09:07	26 JUN 31.7% 00:27 10:28	27 JUN 43.1% 00:49 11:49	28 JUN 55.0% 01:09 13:10
29 JUN 66.7% 01:29 14:32	30 JUN 77.4% 01:48 15:54	1 JUL 86.6% 02:10 17:17	2 JUL 93.6% 02:36 18:39	3 JUL 98.1% 03:09 19:56	4 JUL ---%* 03:52 21:03	5 JUL 99.9% 04:45 21:57
6 JUL 99.1% 05:49 22:38	7 JUL 95.9% 06:59 23:10	8 JUL 90.7% 08:11 23:34	9 JUL 83.8% 09:23 23:54	10 JUL 75.7% --- 10:32	11 JUL 66.7% 00:11 11:40	12 JUL 57.2% 00:27 12:47
13 JUL 47.5% 00:42 13:54	14 JUL 37.8% 00:58 15:01	15 JUL 28.5% 01:16 16:10	16 JUL 19.8% 01:37 17:20	% Illumination ☀ Moonrise time ☾ Moonset time		

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

All rise and set times are given in BST

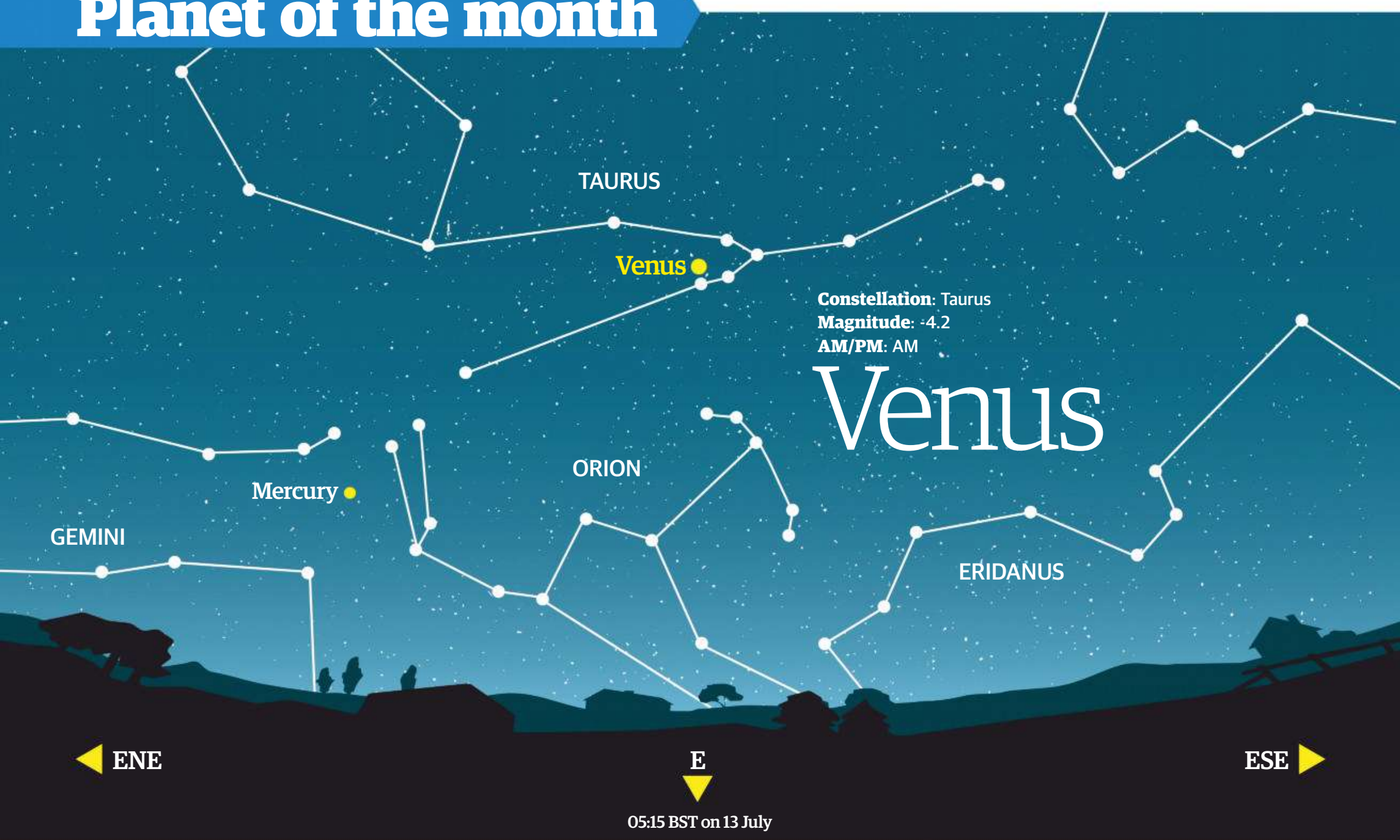
	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	18 JUNE	07h 02m 16s	+21°19'14"	Gemini	+2.3	06:12	22:17
	24 JUNE	06h 56m 27s	+19°48'58"	Gemini	+3.8	05:53	21:37
	1 JULY	06h 40m 08s	+18°40'19"	Gemini	+5.7	05:16	20:46
	8 JULY	06h 25m 07s	+18°31'26"	Gemini	+3.6	04:35	20:03
	15 JULY	06h 23m 21s	+19°21'00"	Gemini	+1.6	04:00	19:39
VENUS	18 JUNE	04h 18m 44s	+18°47'36"	Taurus	-4.3	03:46	19:17
	24 JUNE	04h 15m 11s	+17°45'37"	Taurus	-4.4	03:25	18:44
	1 JULY	04h 18m 02s	+17°12'34"	Taurus	-4.5	03:04	18:15
	8 JULY	04h 27m 26s	+17°14'33"	Taurus	-4.5	02:45	17:58
	15 JULY	04h 42m 12s	+17°40'24"	Taurus	-4.5	02:30	17:47
MARS	18 JUNE	23h 40m 28s	-05°10'09"	Aquarius	-0.3	01:16	12:31
	24 JUNE	23h 54m 31s	-03°48'59"	Aquarius	-0.4	01:00	12:29
	1 JULY	00h 10m 25s	-02°17'05"	Pisces	-0.5	00:41	12:25
	8 JULY	00h 25m 43s	-00°49'02"	Pisces	-0.6	00:21	12:20
	15 JULY	00h 40m 20s	+00°34'06"	Cetus	-0.8	23:57	12:14
JUPITER	18 JUNE	19h 48m 41s	-21°21'13"	Sagittarius	-2.7	22:52	07:09
	24 JUNE	19h 46m 03s	-21°28'56"	Sagittarius	-2.7	22:27	06:42
	1 JULY	19h 42m 38s	-21°38'32"	Sagittarius	-2.7	21:57	06:10
	8 JULY	19h 38m 57s	-21°48'25"	Sagittarius	-2.7	21:27	05:38
	15 JULY	19h 35m 09s	-21°58'13"	Sagittarius	-2.7	20:57	05:06
SATURN	18 JUNE	20h 11m 17s	-20°12'06"	Capricornus	+0.3	23:07	07:39
	24 JUNE	20h 09m 50s	-20°17'09"	Capricornus	+0.3	22:43	07:14
	1 JULY	20h 07m 59s	-20°23'30"	Capricornus	+0.2	22:14	06:44
	8 JULY	20h 05m 59s	-20°30'12"	Sagittarius	+0.2	21:45	06:14
	15 JULY	20h 03m 52s	-20°37'05"	Sagittarius	+0.1	21:16	05:43



This month's planets

Venus takes the morning watch over the next few weeks, alongside Mars, Jupiter, Saturn and Uranus

Planet of the month



Venus is usually the first planet people spot in the sky because it is so easy to see. At its best Venus is the brightest, most beautiful object in the sky, after the Sun and Moon of course. It's ironic that Venus' magnificent brightness is the very same reason why its surface is always hidden from us. The planet has an atmosphere of carbon dioxide so thick it appears opaque from Earth. With no gaps in the planet's clouds its surface can never be seen from Earth, but space probes fitted with radar instruments have mapped it, revealing it has continent-like land masses with towering mountain ranges, deep valleys, wide plains and even volcanoes. Despite some tantalising observations in recent years, planetary scientists are still unsure if any of those volcanoes are active.

Back at the start of the year, and into spring, Venus dominated the evening sky. You probably saw it shining there, lantern bright, outshining every other star and planet in the sky. Venus has since fallen past the Sun and moved into the morning sky, and it will spend the whole of our observing period there as a 'morning star'. In contrast to its stunning appearance at the start of the year, through June - despite its magnitude of -4.2 - Venus' low altitude in the bright pre-dawn sky means it will be less than conspicuous. Thankfully, as the mornings pass the visibility of the fascinating world - often called Earth's Twin because of its similar size to our own planet - will improve as it moves away from the Sun, and it will have company in that darker sky too.

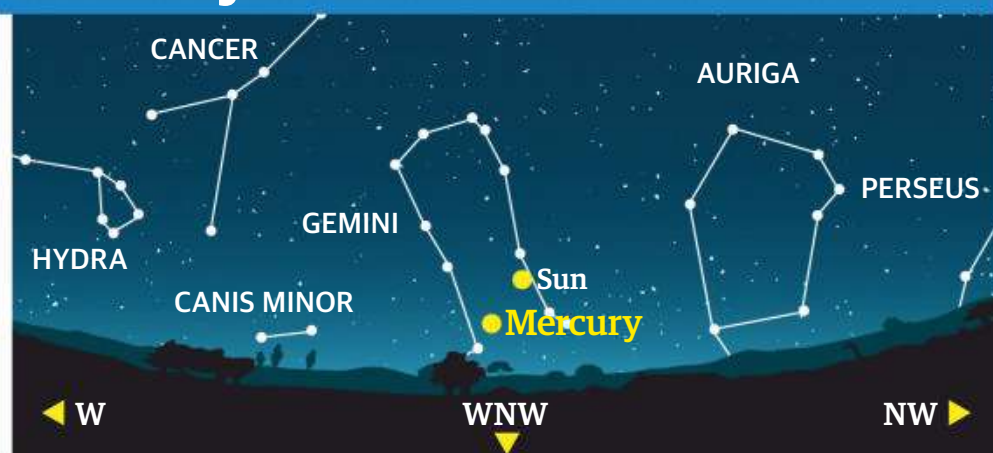
By the end of June Venus will be shining in the constellation of Taurus, positioned almost directly between the V-shaped Hyades star cluster and the 'mini Big Dipper' of the Pleiades cluster. Cross your fingers for clear skies before sunrise on the morning of 9 July because that's when Venus will have moved to sit right in the middle of the Hyades, looking very attractive through a pair of binoculars or a small telescope.

By 13 July Venus will have slid some way to the east and will be shining just one degree, or two Moon widths, away from the bright-orange star Aldebaran. On 15 July, at the end of our observing period, Venus will have moved clear of Aldebaran and will be some 25 degrees to the lower left of a waning crescent Moon.



This month's planets

Mercury 20:15 BST on 30 June



Constellation: Gemini

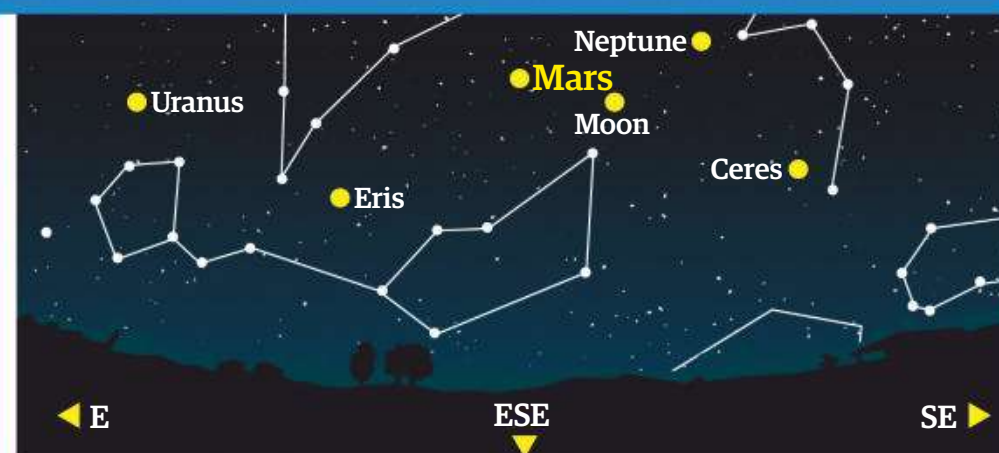
Magnitude: +2.4

AM/PM: PM

At the start of our observing period Mercury, the closest planet to the Sun, is an evening star, visible after

sunset directly beneath the stars Castor and Pollux. However, its low magnitude and low altitude in a bright sky will make it hard to see without help from binoculars or a small telescope.

Mars 03:15 BST on 11 July



Constellation: Aquarius

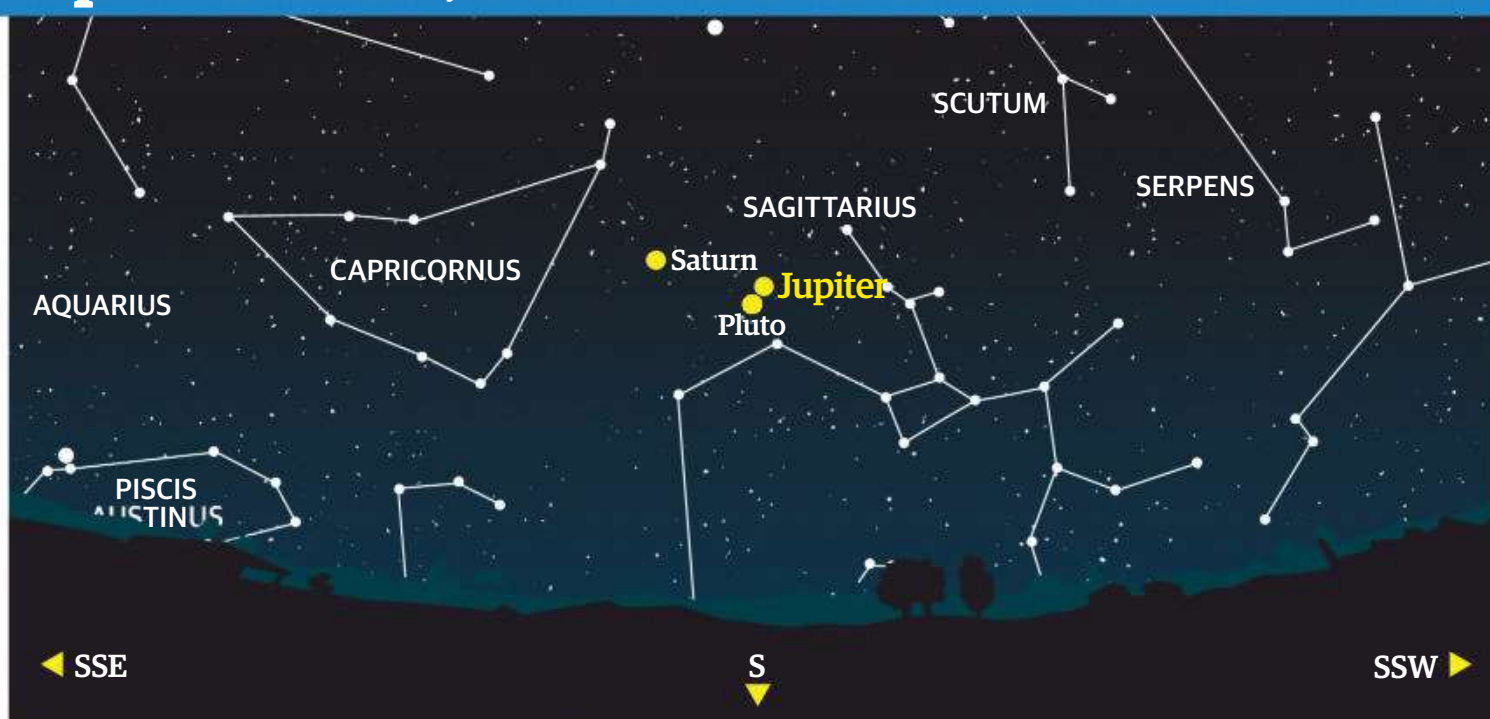
Magnitude: -0.2

AM/PM: AM

Mars is visible low in the east in the early hours before dawn at the start of our observing period. You'll see

the Red Planet shining like a bright, orange 'star' some distance off to the lower left of the close pairing of yellow-white Saturn and blue-white Jupiter, which will be shining low in the southeast.

Jupiter 03:00 BST on 6 July



Constellation: Sagittarius

Magnitude: -2.7

AM/PM: AM

At the start of our observing period Jupiter will be rising around midnight, which will technically make it a morning planet. You'll find it shining like a bright, blue-white star to the upper left of the stars which form the handle of the famous 'Teapot' asterism of Sagittarius. After rising in the southeast, with Saturn close by on its left, it will trace out a low arc across the southern sky through the quiet hours until dawn. Between 5 and 7 July the Moon, bright and full, will pass beneath Jupiter. On the 6th Jupiter will be shining directly above it.

Saturn 02:00 BST on 6 July



Constellation: Capricornus

Magnitude: +0.3

AM/PM: AM

Yellow-white Saturn will be shining just to the lower left of brighter Jupiter. You'll see it low in the

southeastern sky after midnight. The full Moon will be shining beneath it on the mornings of 6 and 7 July. Saturn is famous for having a system of beautiful rings, but you'll need a telescope to see them.

Uranus 06:00 BST on 14 July



Constellation: Aries

Magnitude: +5.9

AM/PM: AM

This won't be a good month for fans of the penultimate planet in the Solar System. The ice-giant world,

four times Earth's diameter, will be low in the southeast before sunrise in the small and unremarkable constellation of Aries, but its magnitude of +5.9 will probably make it too faint to see.



Top tip!

The best time to see Theophilus is when it is near the terminator. That's when it looks most dramatic through a telescope.

Moon tour

Theophilus

How to find one of the most striking but overlooked craters on the lunar surface

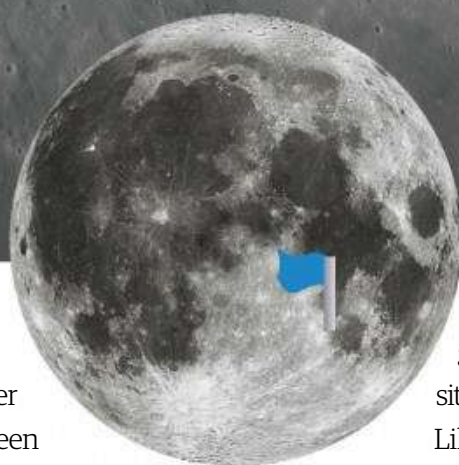
Lunar observers often feel frustrated during summer because the Moon's low altitude means they have to see it through the murk and haze that lingers above the horizon, so the Moon often appears bloated and its image wobbles and warps in eyepieces. However, the Moon is always a lovely sight through a telescope, so this summer why not try and track down something new - or something you'll almost certainly have seen before but not spent time looking at properly.

Set between the dark stain of Mare Nectaris to the southeast and Sinus Asperitatis in the north, Theophilus is one of the most striking craters on the whole of the Moon - or at least on the side that faces us. Named after the 23rd Pope of Alexandria, who made no friends in religious circles by ordering the slaying of 10,000 monks, the crater is best seen during the lunar month for four or five days after new Moon and just before it reaches last quarter, when it lies close to the terminator. Like most lunar features, during full Moon - when the Sun is overhead - Theophilus' features are washed out. It then looks more like a white smoke ring than a pit, but is still easy to see.

Theophilus is a classic 'Tycho class' impact crater, deep and round, closely resembling better known 'celebrity' craters like Copernicus, Eratosthenes and of course Tycho itself. Roughly 100 kilometres (62

miles) wide and 3.2 kilometres (1.9 miles) deep, Theophilus' floor is flat because it was flooded with lava after its formation, but since then it has been spattered with numerous smaller craters like a road sign pitted with buckshot. The largest of these, 'Theophilus B' is eight kilometres (4.9 miles) wide and was blasted out of the crater's northwestern wall. A clover-leaf cluster of four 1.4-kilometre (0.8-mile) high mountainous peaks rises up from Theophilus' smooth floor. High magnifications show the four peaks looking like a single peak hacked into four separate pieces; when the Sun's light strikes them at low angles, the tallest two peaks cast dramatic triangular shadows across the western side of the crater floor.

Like many of the other great lunar craters, Theophilus forms one half of a striking double crater. It was formed by an impact which obliterated the northeastern corner of an existing crater, Cyrillus. Unlike Tycho, however, no major ejecta rays can be seen stretching away from Theophilus, not even at full Moon when such rays tend to jump out at us. We know that a huge amount of material was scattered across the Moon when it was formed because some of it was found almost 3,000 kilometres (1,864 miles) away when the crew of the penultimate Apollo



mission, Apollo 16, explored and gathered samples from their landing site in the Descartes Highlands in 1972. Like many other craters its size,

Theophilus has a sharp rim and gently sloping walls. These are broken up with terraces, ledges and shelves on the eastern side, while much of the floor on the crater's western side has been covered by landslides. In mid-June, with the Moon a waning crescent in the pre-dawn sky, approaching full, Theophilus is in total darkness. It won't be visible at all until the evening of 26 June when the terminator, the line between lunar day and night, sweeps over it again just before first quarter. For the next couple of evenings the crater will appear at its most dramatic as the Sun's low-slanting rays cast stark shadows behind and within it. When the Moon reaches full on 4 July Theophilus will be fully illuminated from the Sun blazing overhead and will show virtually no surface relief, reduced to a light coffee cup ring. By 8 July the great crater will become prominent again as the Moon begins to wane and the terminator approaches it once more. The terminator rolls over the crater again on the evening of 10 July and we will lose sight of it as it is plunged into darkness. We won't see it again during this issue's observing period.

Naked eye & binocular targets

It doesn't get fully dark at this time of year, but there are still fascinating things to see in the night sky

Deneb (Alpha Cygni)

Shining at magnitude +1.3, making it the 19th-brightest star in the sky, blue giant star Deneb is 2,600 light years away from Earth. Some 200-times wider than the Sun, Deneb is huge - if you replaced our star with it, it would extend out to Mars' orbit.

Vega (Alpha Lyrae)

The fifth-brightest star in the sky, magnitude +0.03 Vega is one of the closest stars to us, only 25 light years away. It was the Pole Star in 12,000 BCE. It spins so rapidly, like an egg wobbling on a table, that it bulges at its centre.

Lyra

Hercules

Cygnus

The Dumbbell Nebula (Messier 27)

This planetary nebula - actually ghostly shells of gas puffed away from a dying star long ago - can just be seen through binoculars on a dark, Moon-free night as a small smoky spot. It got its nickname from its shape when seen in powerful telescopes.

Vulpecula

Serpens
Cauda

Messier 29

Many night-sky observers think that this pretty 7th-magnitude open star cluster looks like a 'mini Pleiades' or 'squashed Big Dipper' through binoculars. It contains 30 or so stars and lies around 6,000 light years away from our Sun.

Sagitta

Delphinus

Altair (Alpha Aquilae)

The third star of the famous 'Summer Triangle', Altair's magnitude of +0.76 makes it the 13th-brightest star in the sky. It is only 17 light years away. The famous science-fiction film *Forbidden Planet* was set on an imaginary planet in orbit around it.

Aquila



North America Nebula
(NGC 7000)

Deep sky challenge

Hunt for clusters and nebulae in Cygnus

No need to put your telescope into hibernation on light summer nights

Let's be honest, June and July are not really the best of months for telescope owners who enjoy looking at faint deep-sky objects.

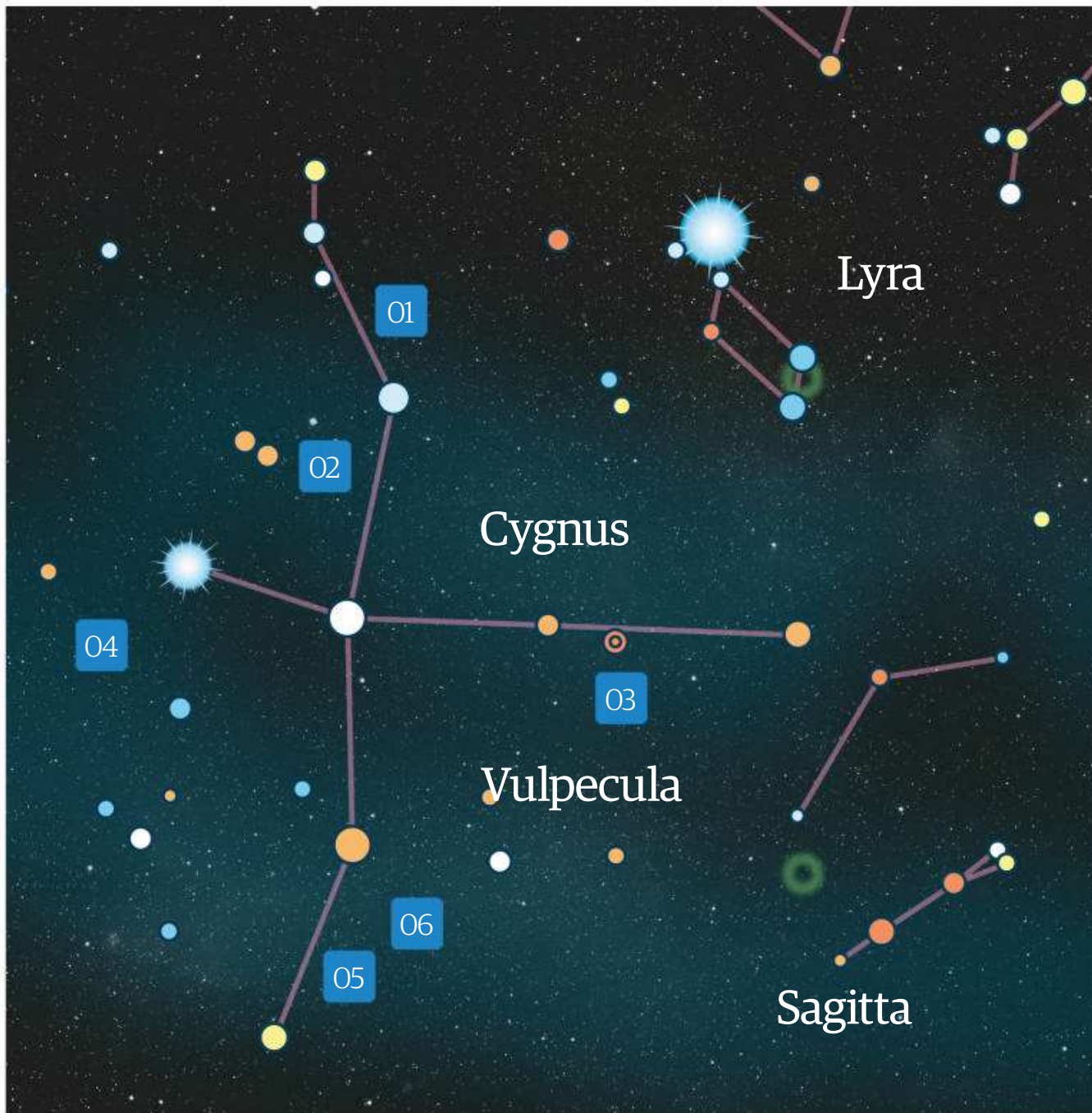
It never gets truly dark, so the faintest galaxies, nebulae and clusters are lost in the never-ending twilight. But there are still a few things to swing your tube around to - especially in Cygnus, which is almost overhead around

midnight - when the night sky is as dark as it is going to get.

Our challenging objects this month might not have the faintest magnitudes, but they will still take some tracking down because of the brightness of the sky. The open star clusters NGC 6811 and NGC 6866 are only small, but they are still attractive sights in the eyepiece

of a medium- or large-aperture telescope. The curved, misty arcs of the Veil Nebula will test your skills as an observer and the quality of your telescope and sky too. Your final challenge, the North America Nebula, might be visible to the naked eye on late Autumn nights, but at this time of year it will play hide and seek with your telescope unless everything is just right.

Source: Wikipedia Commons © Alex Weinstein



1 NGC 6811

This magnitude +6.8 open cluster, just under 4,000 light years away, is little more than a scattering of pinprick blue stars. A high-power eyepiece will show the 'hole' in its centre.

2 NGC 6866

At magnitude +7.6, this open cluster is another small scattering of a dozen or so icy-blue stars. Its roughly triangular shape is best seen in a high-power eyepiece.

3 NGC 6834

This magnitude +7.8 open cluster is faint but rich, with 50 or so faint stars and a line of brighter stars cutting across it. A high-power eyepiece in a large telescope will give the best views.

4 North America Nebula (NGC 7000)

Although this nebula will be visible to the naked eye later in the year, right now you'll need a large telescope and a low-power eyepiece to pick it out from the bright background sky.

5 Eastern Veil Nebula (NGC 6995)

This faint, misty arc is the eastern part of a ring-shaped nebula left behind after a giant star exploded. You'll need a large telescope and averted vision to see it during June and July!

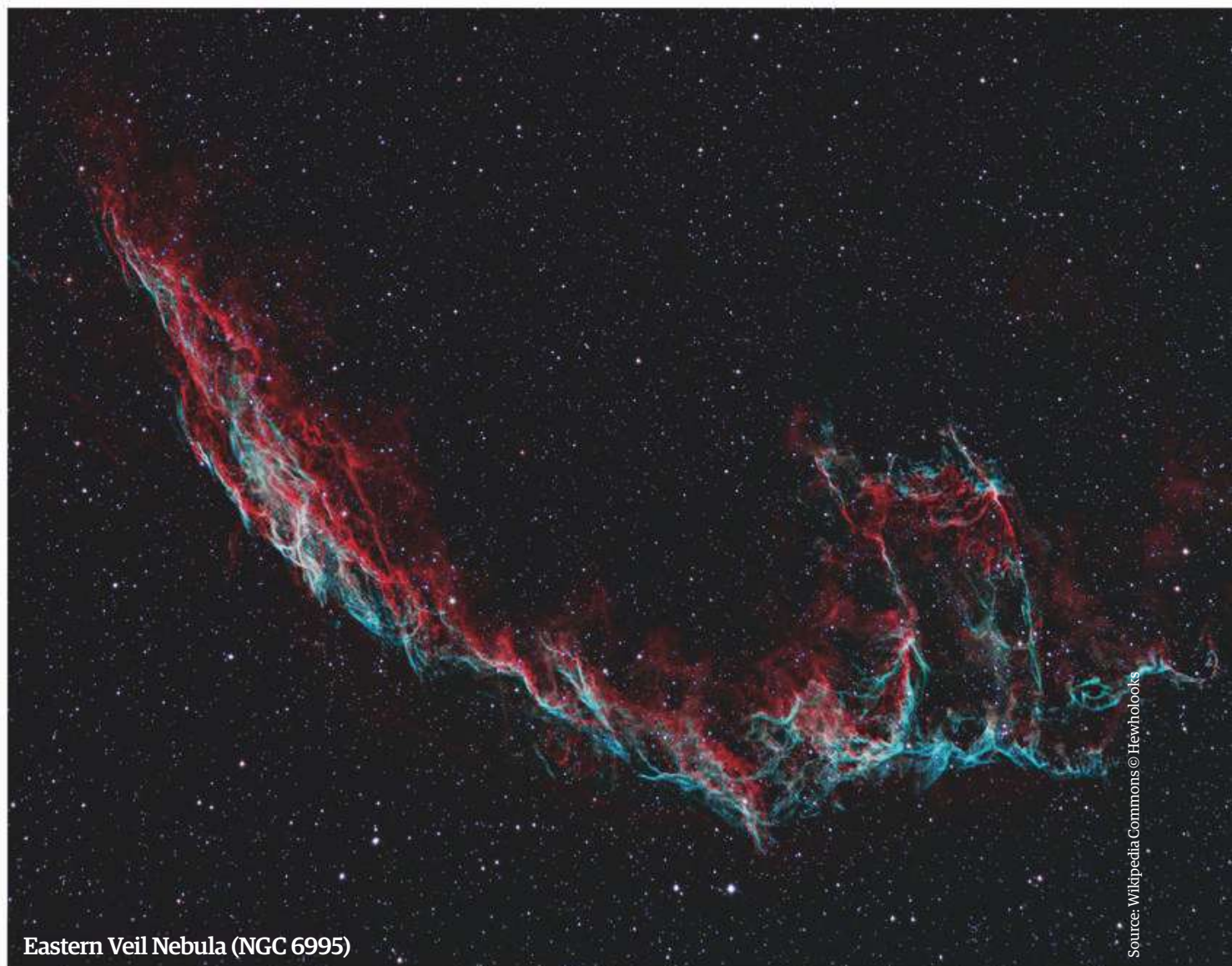
6 Western Veil Nebula (NGC 6960)

Also known as the 'Witch's Broom', the western arc of the Veil Nebula can be seen on summer nights through the high-power eyepieces of medium and large telescopes.

NGC_6866



Eastern Veil Nebula (NGC 6995)





The Northern Hemisphere

Myriad targets are on offer for astronomers with the right equipment

The constellations of Lyra, Aquila, Hercules, Sagittarius, Scorpius and Ophiuchus are in easy reach this month. Fans of tight-knit globular star clusters should turn their attention to the constellations of Ophiuchus and Hercules, where they will be rewarded with sights of the extremely stellar-rich Messier 10, Messier 12, Messier 13, Messier 14 and Messier 92.

Meanwhile, astrophotographers will get great enjoyment from the binary star system Rho Ophiuchi in Ophiuchus, which is surrounded with a red emission nebula and very impressive light and dark dust lanes. Cygnus is another goldmine, with the Veil Nebula, Fireworks Galaxy and the Crescent Nebula being excellent choices for observation in particular.

Using the sky chart

This chart is for use at 22:00 (BST) mid-month and is set for 52° latitude.

- 01 Hold the chart above your head with the bottom of the page in front of you.
- 02 Face south and notice that north on the chart is behind you.
- 03 The constellations on the chart should now match what you see in the sky.



Magnitudes

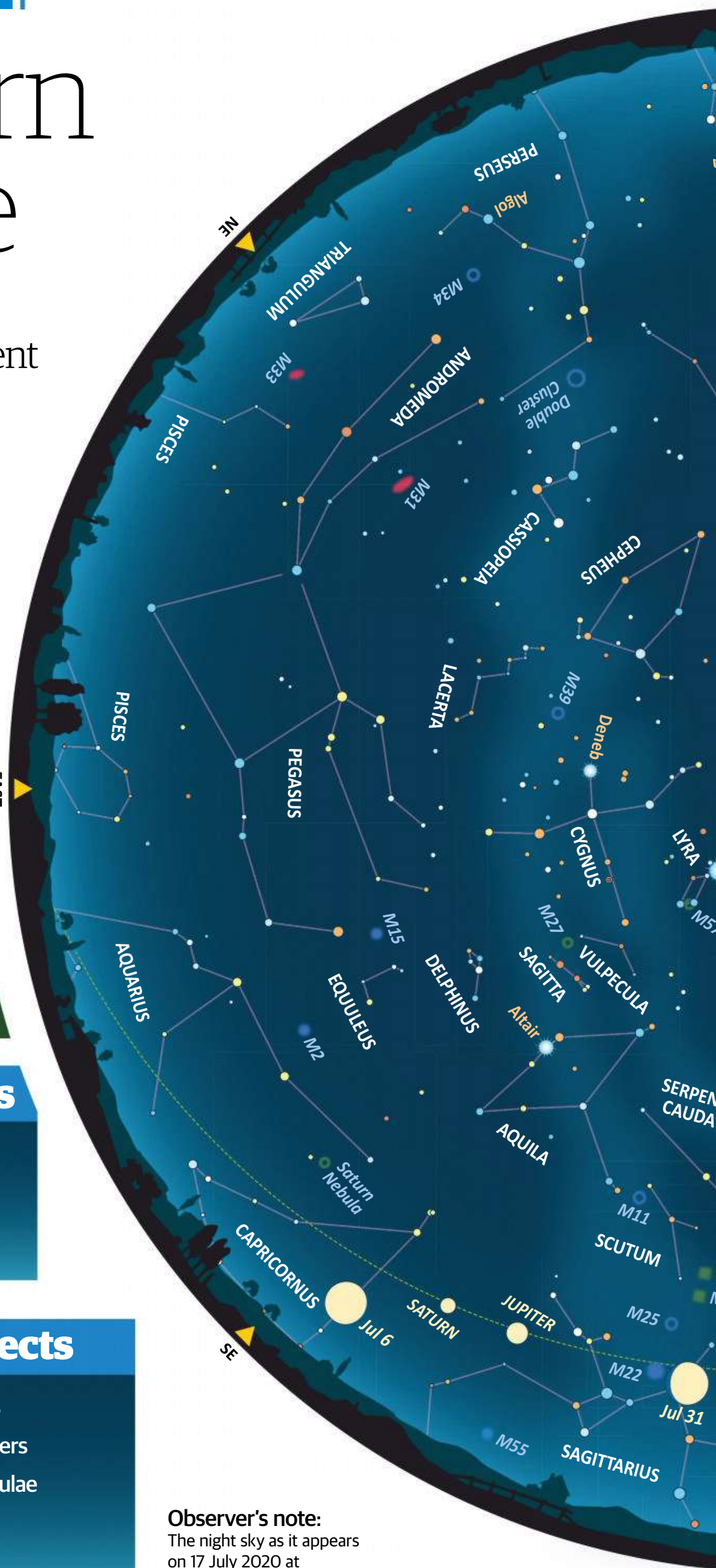
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- | | |
|-------|-----|
| • O-B | • G |
| • A | • K |
| • F | • M |

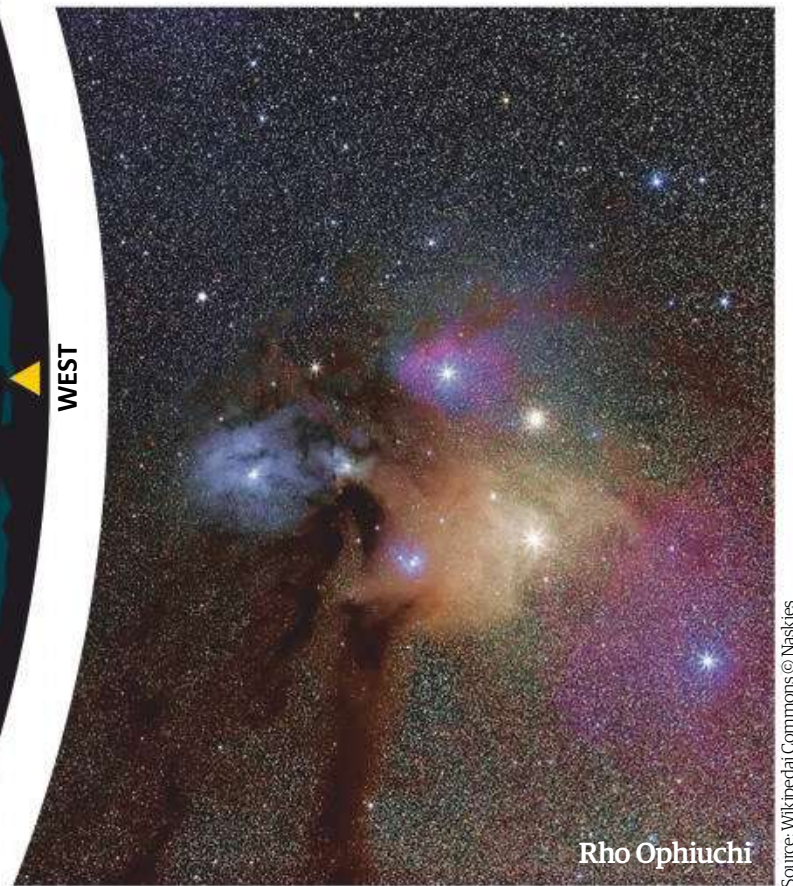
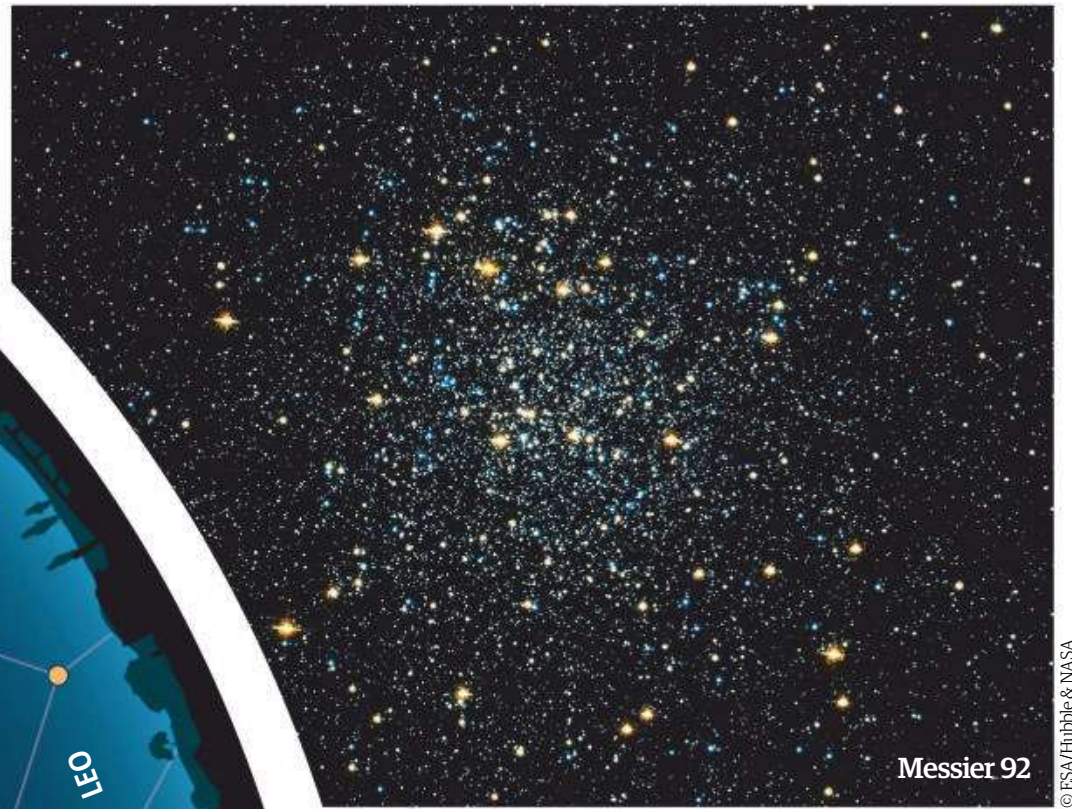
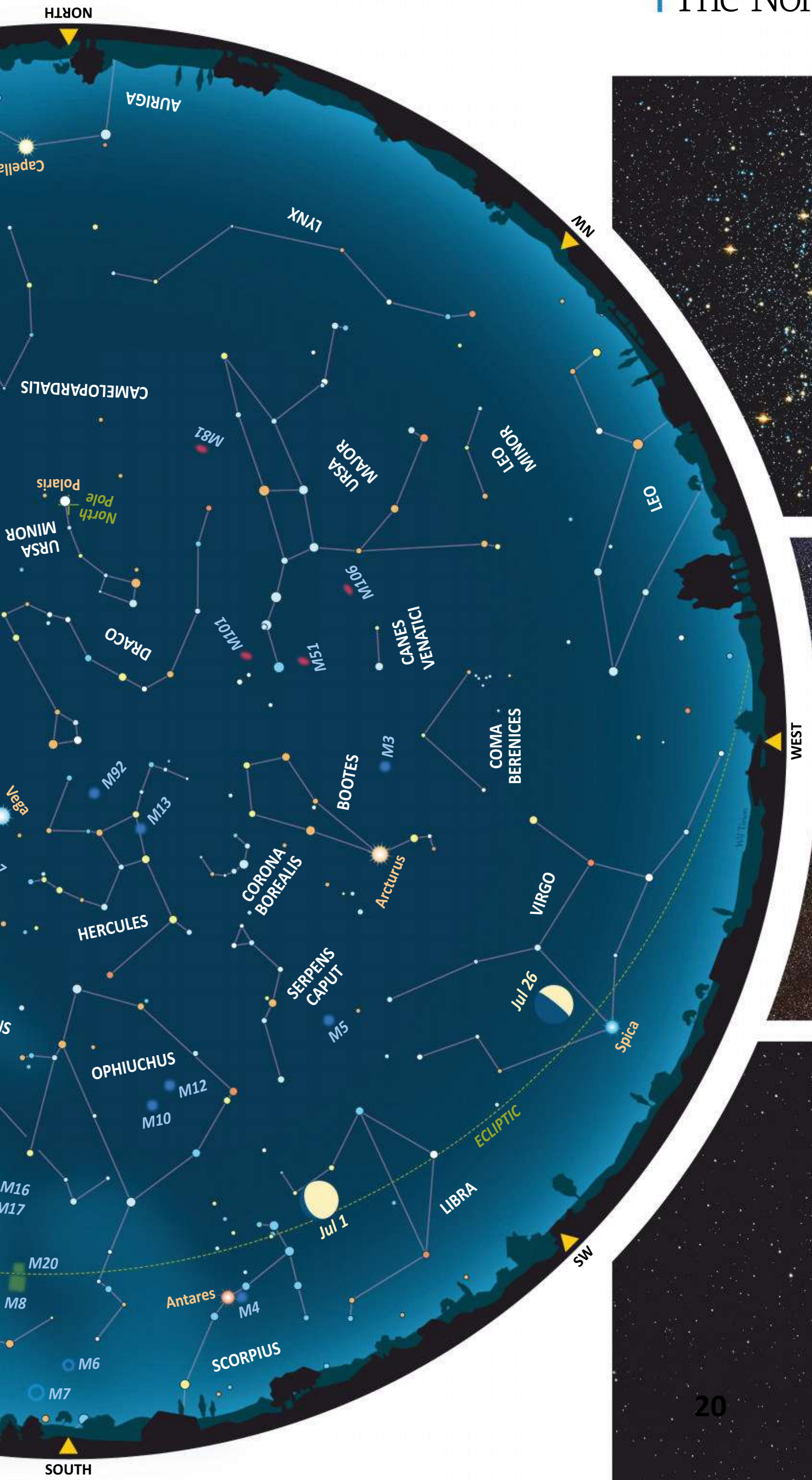
Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 17 July 2020 at approximately 22:00 (BST)

The Northern Hemisphere





Celestron NexStar 6SE

A high-quality telescope for beginners and intermediate astronomers alike, the Celestron NexStar 6SE is an instrument that promises years of usage

Telescope advice

Cost: £1,149.00 / \$1,405.00

From: David Hinds Ltd.

Type: Schmidt-Cassegrain

Aperture: 5.91"

Focal length: 59"

Best for...

-  Beginners and intermediate
-  High budgets
-  Planetary viewing
-  Lunar viewing
-  Deep-sky objects
-  Basic astrophotography

It's not often that we come across a telescope that's an 'all-rounder', but we were quite taken with the Celestron NexStar 6SE, especially since it can be used by both beginners and astronomers who have a good night-sky knowledge. It's also quite difficult to outgrow this telescope given what it can offer and how easy it is to accessorise with extra eyepieces and other kit. The 25mm Plössl eyepiece supplied gives a magnification of 60x, but we'd advise purchasing a selection of eyepieces and filters - bearing in mind that the highest useful magnification is 354x - to get the very best out of this telescope.

Setting this Schmidt-Cassegrain up took next to no time at all, and we were impressed with the quality of many of its components. The robust build of the NexStar 6SE promises to last years of observing sessions, provided it is treated with care. We would recommend purchasing a dew shield for this telescope though, since catadioptric telescopes can succumb to moisture.

Weighing in at 9.53 kilograms (21 pounds), the telescope is a touch on the heavy side, but given the technology and components compacted into one instrument, we weren't surprised, seeing this only as a minor inconvenience to those who would have preferred a lighter 'scope. However, quite a large flaw in the telescope's design is that

it needs eight AA batteries to operate the computerised fork mount. Sadly the NexStar 6SE drains batteries quite quickly, making using it quite frustrating - and with the potential for becoming quite expensive with more frequent use. We found that even with rechargeable batteries the telescope would act strangely with low charge, so we strongly recommend purchasing an AC power cord from Celestron, because unfortunately this is not included with the telescope.

Celestron promises a lot when it comes to the operational abilities of this instrument, so we were delighted to discover that the NexStar 6SE did exactly what the manufacturer said when we took it out to test on a clear December 2019 evening. Its star alignment, using the SkyAlign technology, was impressively simple, and it wasn't long before we began touring the winter night sky.

Our first target was the Orion Nebula, which can be found just below Orion's Belt and which is visible to the naked eye as a fuzzy patch. Instructing the NexStar to view this diffuse nebula, the computerised mount ran smoothly and was very accurate at locating objects: the Trapezium Cluster, for instance, is nestled at the heart of the Orion Nebula, and was seen to be aligned close to the centre of the field of view. When we brought the heart of the nebula into view we did notice a degree of vibration while focusing, but once finished views could be taken in with no hindrance. Thanks to the excellent StarBright XLT optical coating our observations of the nebula and its stellar members were very crisp, bright and clear, with no defects in the optics to speak of.

While the telescope slews to its target - this model possesses nine speeds - the mount does make a great deal of noise, particularly when we used the moderate to fast settings. If you find the noise off-putting and are happy to observe without a computerised mount, it's quite easy to switch over to a manual one given that the tube possesses a Vixen-style dovetail. Remember though, you will need a Vixen adapter if you want to fit the tube to another Celestron mount.

Heading back inside to warm up with a cup of tea, we decided to give the NexStar's lunar, solar and sidereal tracking a test. Upon returning to the telescope 30 minutes later, we found that the star hadn't drifted out of the field of view, highlighting



Above: The Schmidt-Cassegrain comes with a 1.25" 25mm eyepiece as well as easy-to-use software and instruction manuals

Left: The fork mount is packed with technology that makes finding your way around the night sky a breeze





"The NexStar revealed well-defined crater walls and lunar mare"

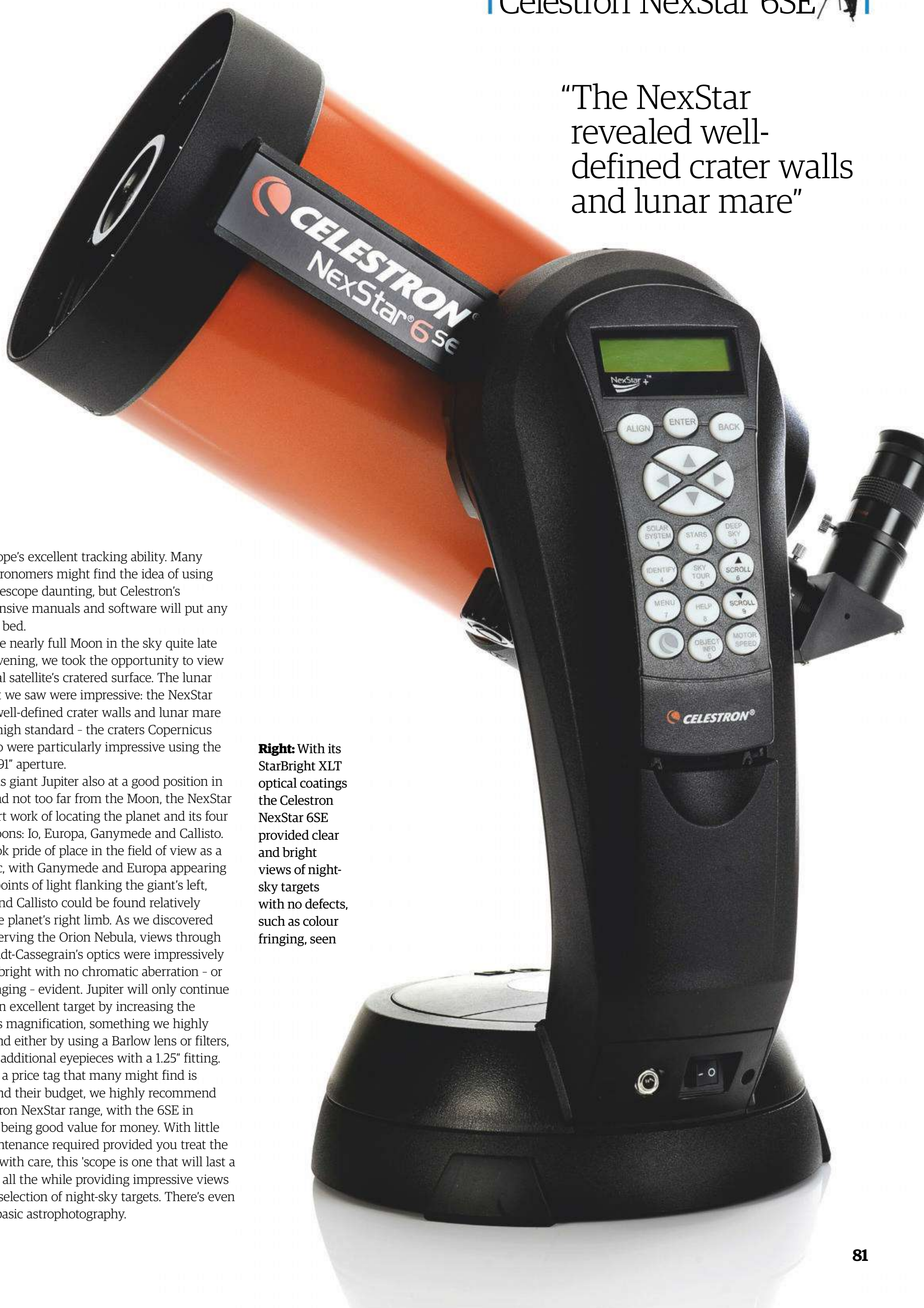
the telescope's excellent tracking ability. Many novice astronomers might find the idea of using a GoTo telescope daunting, but Celestron's comprehensive manuals and software will put any worries to bed.

With the nearly full Moon in the sky quite late into the evening, we took the opportunity to view our natural satellite's cratered surface. The lunar views that we saw were impressive: the NexStar revealed well-defined crater walls and lunar mare to a very high standard - the craters Copernicus and Tycho were particularly impressive using the modest 5.91" aperture.

With gas giant Jupiter also at a good position in the sky and not too far from the Moon, the NexStar made short work of locating the planet and its four largest moons: Io, Europa, Ganymede and Callisto. Jupiter took pride of place in the field of view as a bright disc, with Ganymede and Europa appearing as sharp points of light flanking the giant's left, while Io and Callisto could be found relatively near to the planet's right limb. As we discovered when observing the Orion Nebula, views through the Schmidt-Cassegrain's optics were impressively clear and bright with no chromatic aberration - or colour fringing - evident. Jupiter will only continue to make an excellent target by increasing the telescope's magnification, something we highly recommend either by using a Barlow lens or filters, as well as additional eyepieces with a 1.25" fitting.

Despite a price tag that many might find is way beyond their budget, we highly recommend the Celestron NexStar range, with the 6SE in particular being good value for money. With little to no maintenance required provided you treat the telescope with care, this 'scope is one that will last a long time, all the while providing impressive views of a wide selection of night-sky targets. There's even room for basic astrophotography.

Right: With its StarBright XLT optical coatings the Celestron NexStar 6SE provided clear and bright views of night-sky targets with no defects, such as colour fringing, seen



Mikhail Kornienko

A spacefarer with a collective 516 days spent above Earth

Mikhail Kornienko recently celebrated his 60th birthday in the comfort of his home planet, as opposed to his 50th and 55th, which were spent in low-Earth orbit. He has been an instrumental figure in modern Russian spaceflight and is a veteran of several expeditions.

Kornienko was born on 15 April 1960 in Syzran, Kuibyshev - now Samara - Oblast, Russia, and completed his basic military service between 1978 and 1980. Afterwards he spent six years as a militiaman in Moscow, and his evenings between 1981 and 1987 were spent gaining a qualification in mechanical engineering.

His journey into space began in February 1998 when he was selected as a cosmonaut candidate, qualifying as a test cosmonaut in December 1999 from the Yuri Gagarin Cosmonaut Training Center in Moscow. He began his International Space Station (ISS) exploits by serving as a backup flight engineer on Expeditions 8 and 15. His time to fly finally came on 2 April 2010 when he blasted off to the ISS for Expeditions 23 and 24, also referred to as Soyuz TMA-18, with fellow cosmonaut Alexander Svortsov and NASA astronaut Tracy Caldwell Dyson. Here he celebrated his golden jubilee in the rarest venue there is. This mission was just a warm up for his main event though, as he and NASA astronaut Scott Kelly would prepare themselves for an incredibly long stay on board the orbiting space station.

The ISS is a high-tech laboratory where scientists take advantage of the microgravity environment, and an experiment that Kornienko and Kelly both partook in was this year-long stay in space. This was in order to determine the long-term effects of microgravity on the male human body. The results from these experiments have been shaping how humanity plans its journey towards Mars and its colonisation. This almost-year-long experiment began on 27 March 2015 and carried on through to 2 March 2016. Kelly and Kornienko were an ideal pair of candidates



Kornienko has celebrated two birthday milestones aboard the ISS

because of their similarity, since they were both Caucasian males in their early to mid-50s. They had both already developed a bit of a rapport too, as Kelly was part of the backup crew to Expeditions 23 and 24.

The results from this experiment, creatively titled the 'One-Year Mission', are still being understood four years later from NASA's point of view. Russia had already had astronauts undertake 300-day stints on board the now-defunct Mir space station, but the country has not shared the data. Before long-duration spaceflight to other planets can commence, space agencies need to conduct more studies, much like the one Kornienko participated in.

During his time in space, Kornienko conducted two extravehicular activities (EVAs), totalling over 12 hours experiencing the harsh environment of nothingness. For all his amazing displays of heroism and bravery, venturing to a place where only a minute fraction of the entire population have dared to go, he has received Russia's most prestigious honorary title, the Hero of the Russian Federation.

"His time to fly came on 2 April 2010 when he blasted off to the International Space Station for Expeditions 23 and 24"

Editorial

Editor-in-Chief **Gemma Lavender**
gemma.lavender@futurenet.com

Art Editor **Jonathan Wells**

Staff Writer **Lee Cavendish**

Production Editor **Nikole Robinson**

Research Editor **Baljeet Panesar**

Senior Art Editor **Duncan Crook**

Photography **Olly Curtis**

Contributors

Stuart Atkinson, Igor Bargatin, Meghan Bartels, David Crookes, Annmarie Eldering, Chelsea Gohd, Kate Isaak, Daniel Kelson, Maggie Lieu, Travis Longcore, Fathi Namouni, Kulvinder Singh Chadha, Giles Sparrow, Amy Thompson

Cover images

NASA; JPL Caltech;

Photography

Alamy; ESA; ESO; NASA; Science Photo Library; Shutterstock; SpaceX; University of Arizona; Wikipedia Commons; All copyrights and trademarks are recognised and respected

Advertising

Media packs are available on request

UK Commercial Director **Clare Dove**

clare.dove@futurenet.com

Senior Advertising Manager **Amanda Burns**

amanda.burns@futurenet.com

0330 390 6036

Account Manager **Garry Brookes**

garry.brookes@futurenet.com

0330 390 6637

International Licensing

All About Space is available for licensing. Contact the Licensing team to discuss partnership opportunities. Head of Print Licensing

Rachel Shaw licensing@futurenet.com

Subscriptions

Email enquiries contact@myfavouritemagazines.co.uk

UK orderline & enquiries **0344 848 2852**

Overseas order line and enquiries **+44 (0)344 848 2852**

Online orders & enquiries www.myfavouritemagazines.co.uk

CRM Director **Louise Dudfield**

Circulation

Head of Newstrade **Tim Mathers**

Production

Head of Production **Mark Constance**

Production Project Manager **Clare Scott**

Advertising Production Manager **Joanne Crosby**

Digital Editions Controller **Jason Hudson**

Production Manager **Frances Twentyman**

Management

Chief Content Officer **Aaron Asadi**

Brand Director **Evan Kypreos**

Head of Art & Design **Greg Whitaker**

Commercial Finance Director **Dan Jotcham**

Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB
Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2050-0548

All contents © 2020 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.



We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill and paper hold full FSC and PEFC certification and accreditation.



Future PLC is a public company quoted on the London Stock Exchange (symbol: FUTR) www.futureplc.com

Chief executive **Zillah Byng-Thorne**
Non-executive chairman **Richard Huntingford**
Chief financial officer **Rachel Addison**

Tel +44 (0)1225 442 244





WORLD OF WARSHIPS

EXPERIENCE 20TH CENTURY NAVAL HISTORY LIKE NEVER BEFORE!

REGISTER AT WARSHIPS.CO.UK

TO RECEIVE A STARTING BONUS WORTH £25
THAT INCLUDES:

THE BRITISH DESTROYER HMS CAMPBELTOWN | BRITISH CRUISER HMS CALEDON | BRITISH BATTLESHIP HMS DREADNOUGHT
7 DAYS OF PREMIUM ACCOUNT | AND MORE.



III CAMPBELTOWN



III CALEDON



III DREADNOUGHT

FREE TO PLAY ON PC

Sky-Watcher®

Be amazed.

SKYMAX MAKSUTOV-CASSEGRAINS

SKYMAX Maksutov-Cassegrains are Conveniently Compact, High-Contrast optical instruments that excel for the High-Power observation of Double-Stars and the surface detail of the Moon and Planets.



Sky at Night
MAGAZINE
★★★★★
REVIEWED IN
Issue 152
January
2018



SKYMAX-102 (AZ-EQ AVANT)

102mm f/12.7
Code 10269
Dual-function
Equatorial/Alt-
Azimuth Mount

SRP
£329



SKYMAX-127 (AZ5)

127mm f/11.8
Code 10262

SRP
£499



SKYMAX-102 AZ-GTi

102mm f/12.7
Code 10264

SRP
£435



SKYMAX-127 AZ-GTi

127mm f/11.8
Code 10265

SRP
£549



"I really liked using this kit... Zipping around the sky and visiting all manner of objects presented it with no challenges."
ASTRONOMY NOW MAGAZINE

"This is a fun system to use... feels like the future of telescope control, certainly for anyone that likes technology"
BBC SKY AT NIGHT MAGAZINE

Please note: AZ-GTi Wi-Fi telescopes are controlled by the users own smartphone or tablet and the free Synscan™ App for iOS or Android



SKYMAX-102 AZ GO-TO

102mm f/12.7
Code 10210

SRP
£399



"Delivers high-contrast, pin-sharp views one has become accustomed to with Sky-Watcher Maksutovs"
BBC SKY AT NIGHT MAGAZINE



SKYMAX-127 AZ GO-TO

127mm f/11.8
Code 10211

SRP
£499



SKYMAX-90 (EQ1)

90mm f/13.8
Code 10673

SRP
£209

"The optics of the review instrument were staggeringly good, giving superb views of the Moon"
BBC SKY AT NIGHT MAGAZINE



SKYMAX-102 (EQ2)

102mm f/12.7
Code 10674

SRP
£315



SKYMAX-127 (EQ3 PRO)

127mm f/11.8
Code 10672/20230
OTA ONLY:
SRP £315
(Code 10672)

SRP
£814



"The rings of Saturn appeared sharply defined... Turning to the Moon it was a revelation... In the deep sky, the SkyMAX performed well on everything from galaxies to nebulae"
BBC SKY AT NIGHT MAGAZINE (OTA reviewed)



SKYMAX-150 (EQ5 PRO)

150mm f/12
Code 10885/20981
OTA ONLY:
SRP £599
(Code 10885)

SRP
£1298



"Jupiter was a mesmerising sight... High contrast optics indeed"
BBC SKY AT NIGHT MAGAZINE



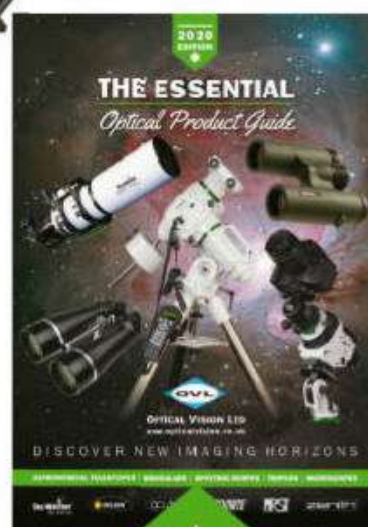
SKYMAX-180 (EQ6-R PRO)

180mm f/15 Code 10217/20855
OTA ONLY: SRP £975 (Code 10217)

SRP
£2404



"This instrument is not just good for visual observing, but also capable of deep-sky astro imaging"
BBC SKY AT NIGHT MAGAZINE (OTA reviewed)



Available from dealers throughout the UK

OPTICAL VISION LIMITED

Full product details at:

www.opticalvision.co.uk
info@opticalvision.co.uk



Email for 88 Page
FREE
Catalogue